SLOVAK GEOLOGICAL MAGAZINE

VOLUME 4 NO 2

ISSN 1335-96X

Geological Survey of Slovak Republic, Bratislava
Dionýz Štúr Publishers

2/98

ISSN 1335-96X

SLOVAK GEOLOGICAL MAGAZINE

Periodical of Geological Survey of Slovak Republic is a quarterly presenting the results of investigation and researches in a wide range of topics:

- **regional geology and geological maps**
- **lithology and stratigraphy**
- **petrology and mineralogy**
- **paleontology**
- **geochemistry and isotope geology**
- **geophysics and deep structure**
- **geology of deposits and metallogeny**
- **tectonics and structural geology**
- **hydrogeology and geothermal energy**
- **environmental geochemistry**
- **engineering geology and geotechnology**
- **geological factors of the environment**

The journal is focused on problems of the Alpine-Carpathian region.

Managing Editor: G. Šipošová
Language review: B. Molák
Technical Editor: G. Šipošová
Address of the publishers: Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava
Printed at: Gupress Bratislava
P
Annual subscription ra e postage

SLOVAK GEOLOGICAL MAGAZINE

VOLUME 4 NO 2

ISSN 1335-96X

Geological Survey of Slovak Republic, Bratislava
Dionýz Štúr Publishers

2/98

Environment, Sedimentary and Structural Evolution

of the
TERTIARY and MESOZOIC SEQUENCES
of the **WESTERN CARPATHIANS**

ESSE WECA conference devoted in memoriam to our former colleague and famous scientific authority Ass. Prof. Rudolf Mock was held on 11 to 12 December, 1997 at the Department of Geology and Paleontology, Faculty of Sciences, Comenius University in Bratislava. The main topic of the conference was paleoecological, biostratigraphical, sedimentological and structural research of the Western Carpathians and adjacent areas. The 45 scientific research workers from the Slovak Republic, Czech Republic, Poland, Ukraine and Hungary took part in the mentioned event. Separate blocks of lectures were devoted to the up-to-date research results of the Mesozoic and Tertiary formations, as well as to the paleogeographic and palinspastic reconstructions of given area.

Apart from the presentation of new knowledge the conference has predominantly contributed to enlarge the scientific cooperation among the Comenius University, Slovak Academy of Sciences, Geological Survey of the Slovak Republic, as well as other geological companies, e.g. Nafta a.s. Gbely. The participation of scientists from Brno, Prague, Krakow, Warszaw, Lwiw, Budapest, Bucuresti and Vienna proved a close collaboration with the foreign institutions.

The conference organizers would like to thank the scientific and organizing committees, as well as the participants for their presentations. The most interesting abstracts are present in this volume.

Ass. Prof. Michal Kováč
Head of the Department
of Geology and Paleontology

Slovak Geol. Mag. 4, 2(1998), 75–85

To rotate or not to rotate: Palinspastic reconstruction of the Carpatho - Pannonian area during the Miocene

MICHAL KOVÁČ[1] & EMŐ MÁRTON[2]

[1]Department of Geology and Paleontology, Faculty of Sciences, Comenius University, Mlynská dolina G, SK-84215 Bratislava, Slovakia
[2]Eötvös Loránd Geophysical Institute of Hungary, Paleomagnetic Laboratory, Columbus u.17-23, H-1145 Budapest, Hungary

Abstract. The correct palinspastic reconstruction of the Carpatho - Pannonian region requires that paleomagnetic observations are also taken into account. Since paleomagnetic data suggest that the major Neogene rotations started with the Ottnangian, we try to picture several geodynamic situations starting with the Eggenburgian pre rotational stage and ending with the Early Pannonian, when the last significant rotation was observed. During this time interval several compressive, extensive and rotational events took place that may be related to subduction pull and stretching of the overriding plate.

Key words: Carpatho-Pannonian region, Neogene, paleomagnetic investigation, block rotations

Introduction

The Carpatho - Pannonian region, due to voluminous prospecting works, can be considered as the natural laboratory of geodynamics. Despite of the very good knowledge of geology, tectonic pattern and evolution of the area, the solution of the Miocene palinspastic reconstructions causes many problems, which led various authors to develop different geodynamic models (Balla 1984, Kováč et al. 1989, Csontos et al. 1992, Kováč et. al. 1994, Csontos a Horváth 1995, Csontos 1995, Morley 1996).

The palinspastic reconstruction of the Carpathian accretionary prism (Outer Carpathians) poses the problems of simple restoration sections because they create the converging restoration paths with large amounts of strike parallel extension. Combination of thrust transport directions changing with time between and within thrust sheets and divergent transport directions helps to minimize the arc-parallel extension necessary (Morley 1996).

The Pannonian Basin System can be treated as the area where, besides large strike slip movements between the semirigid blocks, back arc extension must have played an important role during the Neogene (Royden 1993). Paleomagnetic data point out the existence of large scale rotation of blocks inside the Carpatho - Pannonian region. For the TISZA - DACIA microplate, more than 70^0 post-Cretaceous clockwise rotation is reported (Márton, 1986, Patrascu et al. 1990, 1994), for the northeastern part of the ALCAPA microplate Pelso and Austroalpine subunits 40 - 50° Ottnangian and 30° Early Badenian counter clockwise rotations were observed (Túnyi and Kováč 1991, Kováč and Túnyi 1995, Márton et al. 1995, Márton and Márton 1996) and the Transcarpathian subunit seems to have rotated in counter clocwise sense by about 30° during the Late Sarmatian - Early Pannonian.

The above mentioned rotations were realized along the semirigid microplates boundaries, but a part also inside their subunits (Márton and Fodor 1995) to compensate the stretching induced by subduction pull (book shelf or domino effect). How to treat the rotations in the Carpatho - Pannonian region by palinspastic reconstructions is a question analogous to the famous Shakespeare's Hamlet sentence "to be or not to be - to rotate or not to rotate"?

The microplates

The pre-Neogene basement units of the Carpatho - Pannonian region can be divided into two microplates (Fig.1): a northern one, called ALCAPA and a southern one, the TISZA-DACIA (Balla 1984, Csontos et al. 1992, Csontos 1995).

The ALCAPA microplate is built up by from the Austroalpine belt (Fuchs 1984) comprising the Eastern Alps and Western Carpathians, and the belt which is compared best to the Southern Alps and to the Internal Dinarides and it is exposed in the Transdanubian Central Range and the Igal - Bukk zone (Kázmér and Kovács 1985, Kázmér 1986, Csontos et al. 1992, Vöros 1993). These two subunits are separated by the Rába line in the west and the Hurbanovo Diósjenő line and rests of the Meliata suture in the central part (Plašienka et al. 1998). There is a third subunit which is the broader area of the Transcarpathian depression. The basement of this subunit consist of fragments from the

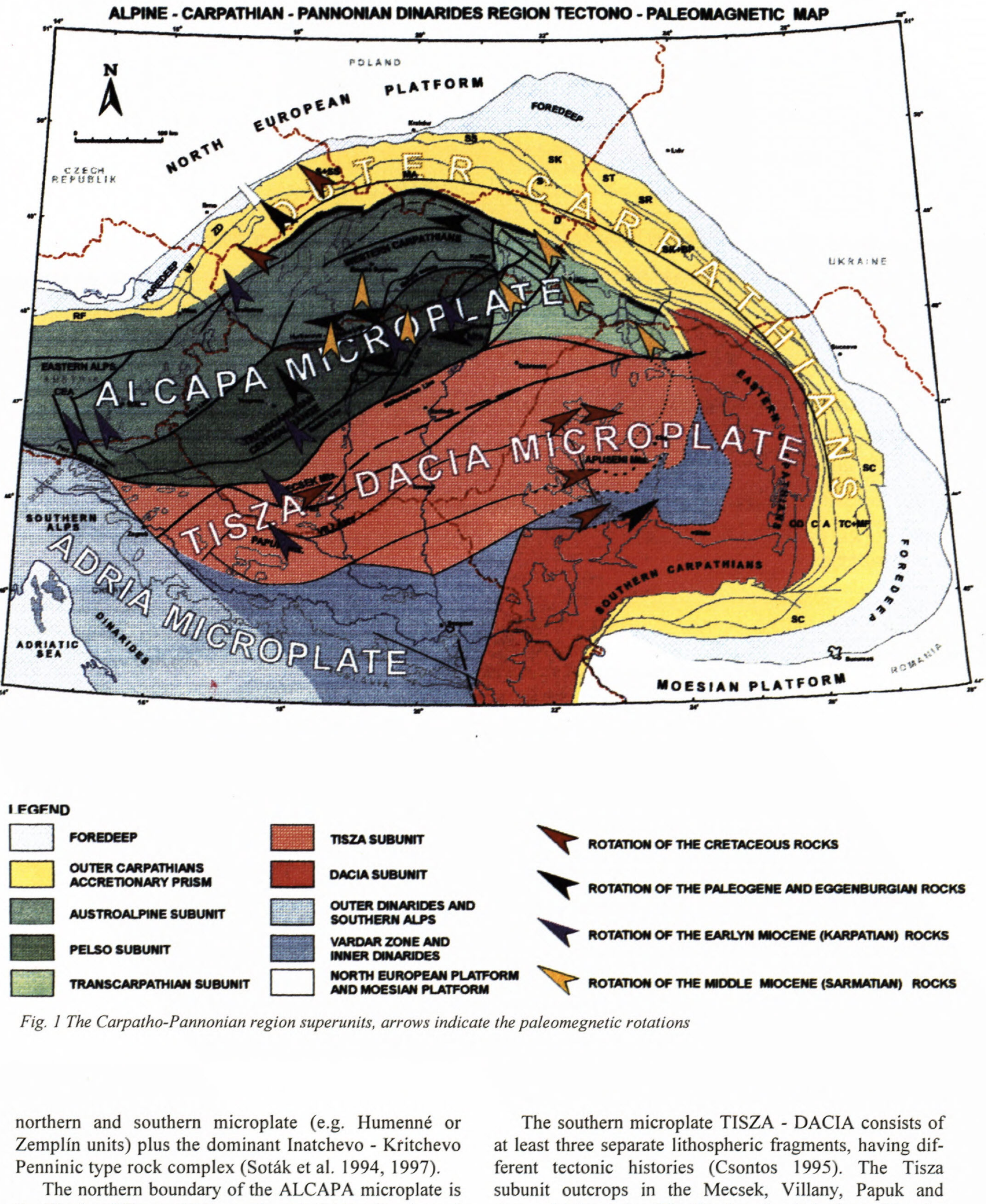


Fig. 1 The Carpatho-Pannonian region superunits, arrows indicate the paleomegnetic rotations

northern and southern microplate (e.g. Humenné or Zemplín units) plus the dominant Inatchevo - Kritchevo Penninic type rock complex (Soták et al. 1994, 1997).

The northern boundary of the ALCAPA microplate is the Pieniny Klippen Belt, an elongated laterally sheared zone composed mainly of Mesozoic rocks (Birkenmajer 1986, Mišík 1997). The southern boundary is represented by the Mid - Hungarian line, a very complicated zone from where the Szolnok unit flysch sequences were folded and thrusted over the TISZA - DACIA microplate (Nagymarosy and Báldi-Béke 1993).

The southern microplate TISZA - DACIA consists of at least three separate lithospheric fragments, having different tectonic histories (Csontos 1995). The Tisza subunit outcrops in the Mecsek, Villany, Papuk and Apuseni Mountains. The Dacia subunit is formed by the Inner and Outer Dacides of the Eastern Carpathians and by the Southern Carpathian units. The contact between the Tisza and Dacia subunits runs through the Metaliferi Mts. and the pre-Tertiary basement of the Transylvanian Basin. This border zone is represented by relicts of the Vardar unit (Sandulescu 1988).

The northern boundary of the Tisza lithospheric fragment is represented by the Mid Hungarian zone, the eastern boundary of the Dacia lithospheric fragment is the thrust front between the Outer Dacides and Internal Moldavide nappes. The southern boundary with the Adria is uncertain, after Csontos (1995) it may be the Sava line and the right lateral contact of the Serbo - Macedonian (Dacia) units with the Vardar zone (Inner Dinarides).

The third major microplate which had influenced the Carpatho - Pannonian realm evolution is the ADRIA microplate. The ADRIA microplate represents the southern boundaries of two superunits mentioned above. (Csontos 1995).

The Early Miocene counter clockwise rotation of the ALCAPA microplate.

The subduction of the Penninic crust below the Alpine thrust front during the Oligocene was followed by the same or similar subduction below the Central Western Carpathian thrust front during the Early Miocene. This process was associated with folding and thrusting of the Magura Nappe Group, Peri Klippen Belt Paleogene, Inatchevo - Kritchevo and Szolnok units during the Eggenburgian (Fig. 2).

The compression in front of the extruding ALCAPA microplate led to the disintegration of the Paleogene forearc basins and the opening of wrench fault furrow type basins (Kováč et al.1997, in press). The documented paleostress field with NW - SE oriented compression initiated a fault pattern with ENE - WSW right lateral strike slips and NE - SW thrusts. Similar fault pattern was described also from the Transdanubian Central Range and western part of the Tisza subunit in the Mecsek Mts. (Csontos et al. 1991. Fodor et al. 1992).

In the eastern part of the TISZA - DACIA microplate, in the Apuseni Mts. and the Transylvanian Basin, N - S compression was dominant during this time, similar to the compression observed in the southeastern margin of the ALCAPA microplate in the Buda and Transcarpathian Basins (Huismans et al. 1997, Kováč et al. 1994, 1995, Márton et al. 1995), mirroring the Penninic type crust subduction between microplates.

During the Ottnangian, beside the Alpine collision with the North European Platform and following eastward oriented extrusion of the ALCAPA microplate (Ratschbacher et al. 1989, 1991), the subduction retreat in front of the Carpathians was the driving force for the Carpatho - Pannonian region evolution.

In the Western Carpathians the Silesian unit was folded and thrusted in front of the Magura, Fore- Magura and Dukla units nappe pile over the Subsilesian and Skola internal zone. The subduction retreat in the Eastern Carpathians led to the Intra Burdigalian tectonic phase, when the front of the Internal Moldavide nappes (Convolute Flysch, Macla and Audia units) was formed (Sandulescu 1988, Micu 1990).

The initial extension compensating the subduction pull can be observed very well in structural and sedimentary record of the ALCAPA microplate, in the southern and central parts. In the NE - SW trending extension the Buda retroarc basin disintegrated and grabens opened along NW - SE normal faults in the southern (Novohrad - Nógrád Basin) and central part (Bánovce and Horná Nitra Basins) of the Western Carpathians (Sztano 1994, Vass et al. 1993, Hók et al. 1995) The subduction pull related stretching of the overriding plate was followed by acid volcanism in vicinity of the Mid Hungarian zone (Szabó et al. 1992).

In the Dacia subunit a NE trending compression induced the N - S to NNE - SSW oriented dextral displacements in the Southern Carpathians, followed by opening of the Getic depression (Ratschbacher et al. 1993, Matenco 1997).

On the basis of the outlined tectonic scenario, the post-Eggenburgian twisting of microplates in the Carpatho - Pannonian domain was influenced more by the subduction retreat in front of the Carpathians, than by the collision between the microplates

This process is documented by the north, northeastward movement of the TISZA - DACIA microplate associated with the Eggenburgian closing of the penninic type Inatchevo - Kritchevo and Szolnok zone in the north and the right lateral displacement of the Dacia subunit along the Internal Moldavide thrust front during the Ottnangian (Matenco 1997). The large clockwise rotation of the TISZA - DACIA microplate during the Early Miocene proposed by Balla (1984), Kováč et al. (1994) and Csontos (1995) seems not to be present.

The ALCAPA microplate counter clockwise rotation of 40^0 - $5O^0$ (Márton et al. 1995) was associated with the Ottnangian right lateral displacement of the semirigid microplate along the TISZA - DACIA northern margin (Mid Hungarian line). The block rotations were compensated by N - S to NNE -SSW oriented sinistral strike slips (Kováč and Hók 1993) and NW - SE trending normal faults acting in the NE - SW oriented initial extension induced by subduction retreat (Fig. 3).

The Early Badenian counter clockwise rotation of the ALCAPA microplate accompanied by possible slight clockwise rotation of the TISZA - DACIA microplate

The late Early Miocene period was influenced by subduction retreat along the front of the Western Carpathians (Fig. 4). The Pouzdřany and Ždanice units were thrusted over the Karpatian foredeep in front of the Magura Nappe Group (Rača unit) in the west, the Subsilesian and Silesian units in the north and Skola unit in the east (Oszczypko and Slaczka 1989, Kováč et al. 1989).

The subduction roll back initiated rifting and extension in the overriding ALCAPA and central part of the TISZA microplates during the Karpatian. The north, northeastward stretching was compensated in the East Alpine - Western Carpathian junction by the NE trending sinistral strike slips, which opened the pull apart Vienna

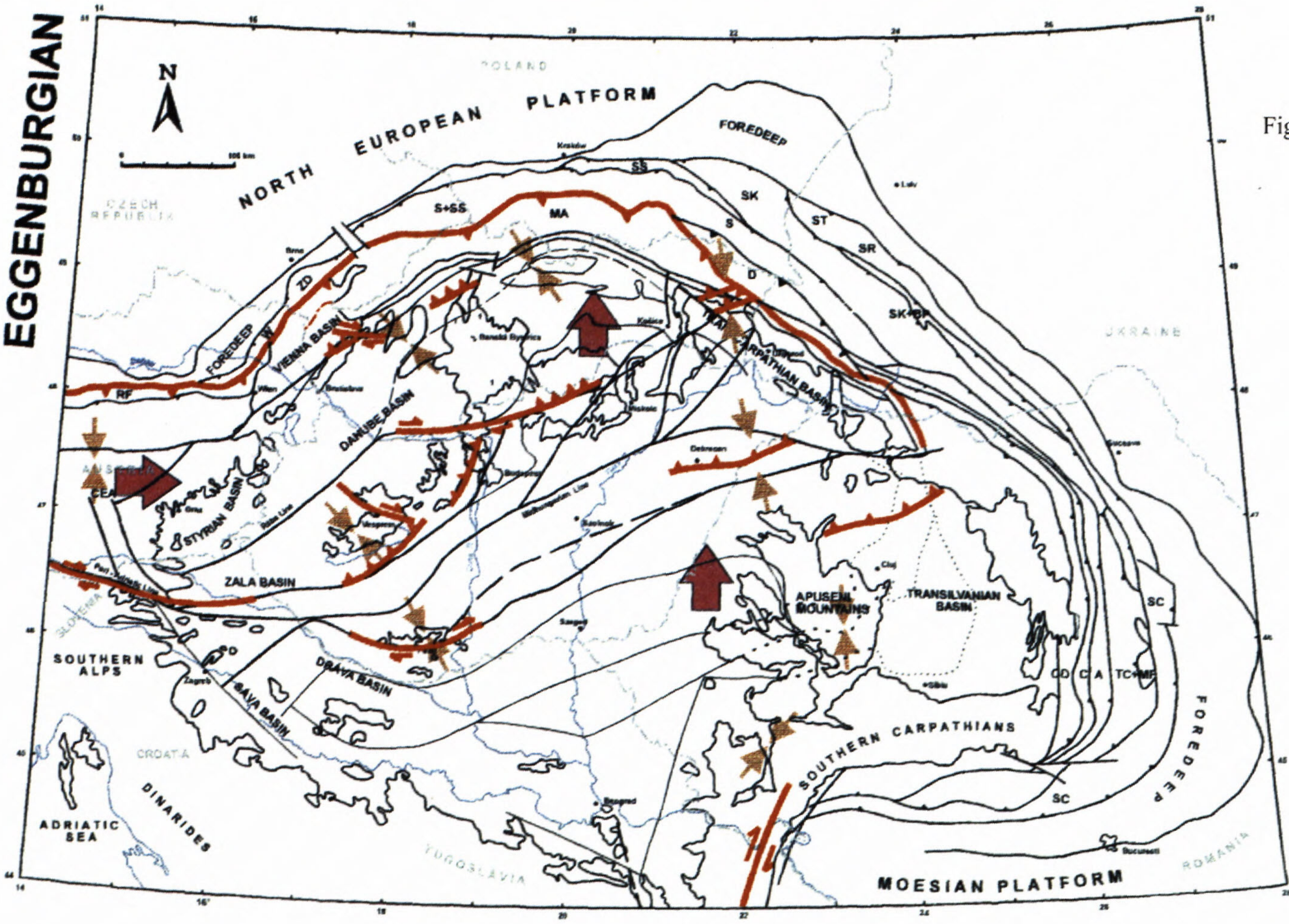

EGGENBURGIAN
N
POLAND
NORTH EUROPEAN PLATFORM
FOREDEEP
CZECH REPUBLIC
S+SS
MA
SS
SK
S
ST
SR
D
SK+BP
UKRAINE
FOREDEEP
RF
VIENNA BASIN
DANUBE BASIN
ZD
TRANSCARPATHIAN BASIN
AUSTRIA
STYRIAN BASIN
ZALA BASIN
APUSENI MOUNTAINS
TRANSILVANIAN BASIN
SC
SOUTHERN ALPS
DRAVA BASIN
SAVA BASIN
CD
C
A
TC+MF
SOUTHERN CARPATHIANS
CROATIA
DINARIDES
ADRIATIC SEA
YUGOSLAVIA
MOESIAN PLATFORM
ROMANIA
FOREDEEP
SC

Fig. 2

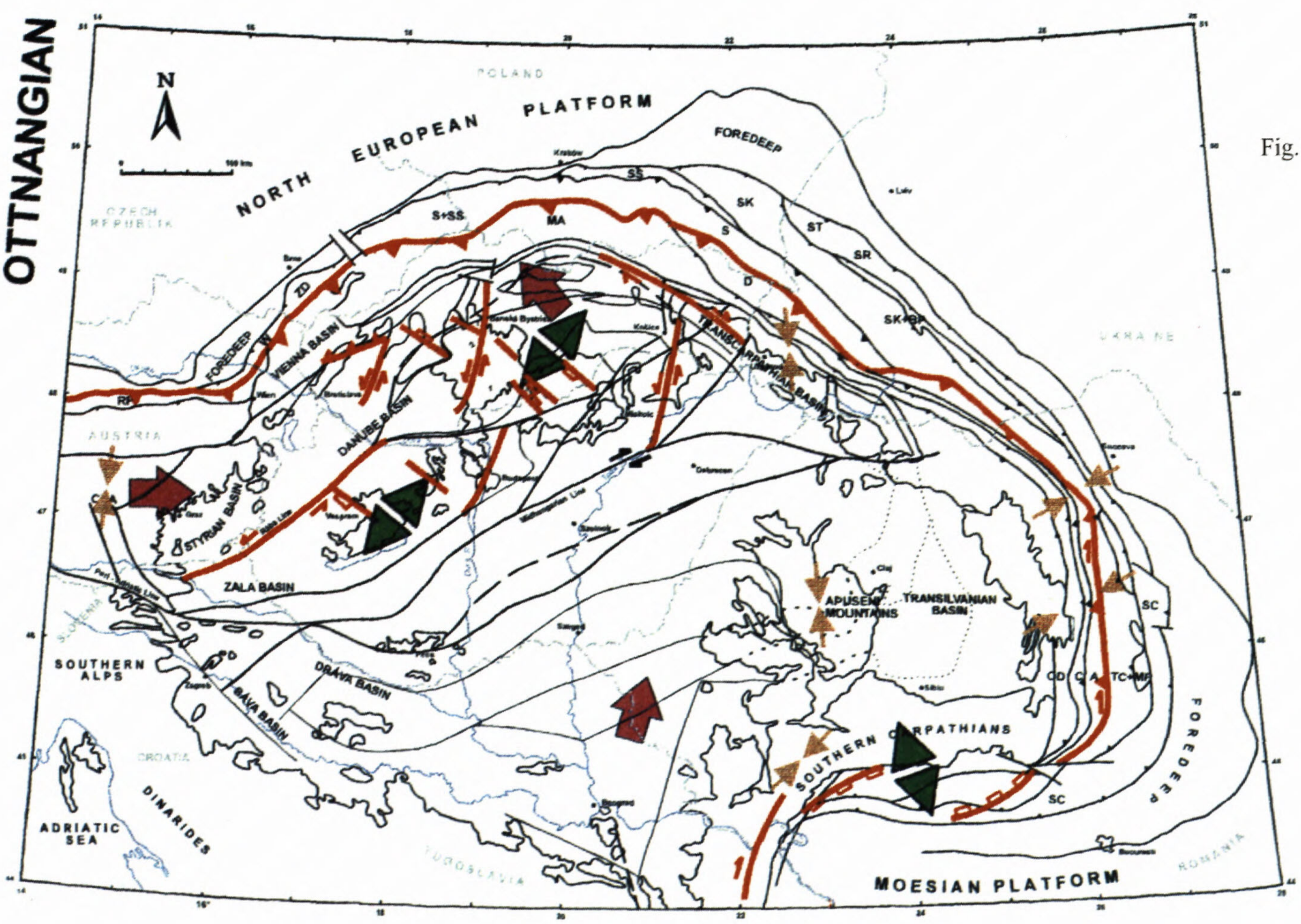

OTTNANGIAN
N
POLAND
NORTH EUROPEAN PLATFORM
FOREDEEP
CZECH REPUBLIC
S+SS
MA
SS
SK
S
ST
SR
D
SK+BP
UKRAINE
FOREDEEP
RF
VIENNA BASIN
DANUBE BASIN
ZD
TRANSCARPATHIAN BASIN
AUSTRIA
STYRIAN BASIN
ZALA BASIN
APUSENI MOUNTAINS
TRANSILVANIAN BASIN
SC
SOUTHERN ALPS
DRAVA BASIN
SAVA BASIN
CD
C
A
TC+MF
SOUTHERN CARPATHIANS
CROATIA
DINARIDES
ADRIATIC SEA
YUGOSLAVIA
MOESIAN PLATFORM
ROMANIA
FOREDEEP
SC

Fig. 3

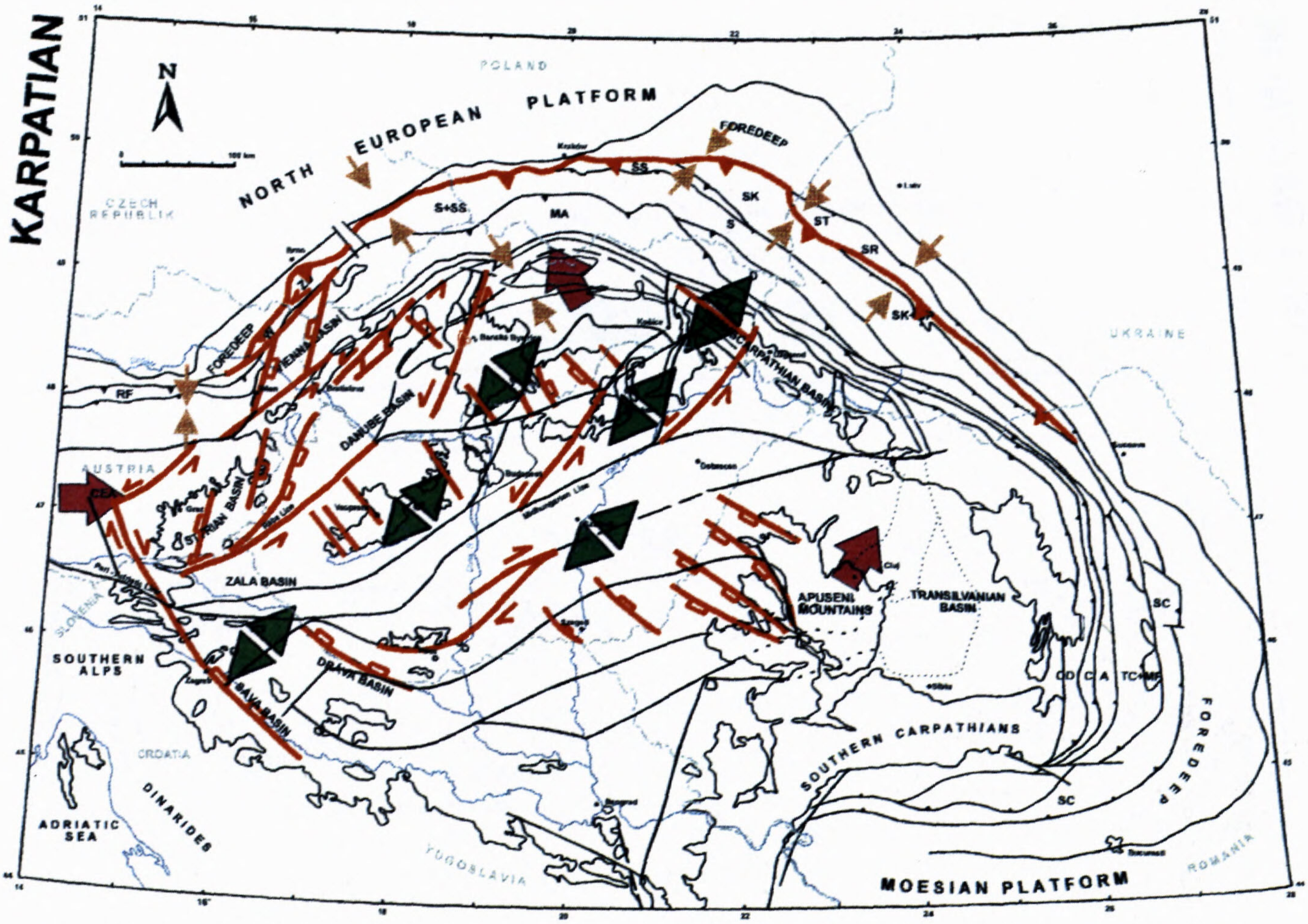


Fig. 4 Major tectonic elements which influenced the Karpatian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

Basin in the paleostress field with N - S oriented main compression (Fodor 1995).

The Karpatian paleostress field with dominant NE - SW oriented extension can be traced in both amalgamated microplates of the Carpatho - Pannonian region. The NW - SE trending normal faults opened the depocenters in the Western Carpathians, Novohrad - Nógrád Basin and Transcarpathian depression in the north, as well as in the Transdanubian Central Range and Great Hungarian Plain in the south (Hók et al. 1995, Kováč et al. 1995, Csontos and Horváth 1995).

The Early Badenian subduction retreat was followed by compression along the whole Carpathian front (Fig.5) and led to the Intra Badenian tectonic phase (Sandulescu 1988) associated with evaporite event (salinity crisis) known from the Carpathian foredeep during the Middle Miocene (Rögl and Steininger 1993, Steininger et al. 1985).

The Western Carpathian active thrust front remained in the north, where it was represented by the Subsilesian and Silesian units (in this time acting as a homogenous thrust sheet) and by the Skola and Borislav - Pokuty units thrusted over the Sambor - Rozniatov unit in the east (Oszczypko and Slaczka 1989).

In front of the Eastern Carpathians, the Tarcau and Marginal Folds units were thrusted over the Early Badenian deposits of the Subcarpathian Neogene unit (Micu 1990). The paleostress fields show a clockwise rotation of the main compression orientation along the Eastern Carpathian front from NE - SW to E - W in the south (Kováč et al. 1995, Matenco 1997).

The post-Karpatian 30° - 40° counter clockwise rotation (Roth 1980, Túnyi and Kováč 1991, Márton and Márton 1996) of the ALCAPA microplate (and also the western part of the Tisza subunit) was caused by the Western Carpathian subduction pull and extension of the overriding plate. The stretching activated the NE - SW to NNE - SSW trending left lateral strike slips (shear zones) and the NW - SE normal faults (Horváth 1993), which compensated the counter clockwise rotation of the semirigid ALCAPA microplate.

Fig. 2 Major tectonic elements which influenced the Eggenburgian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

Fig. 3 Major tectonic elements which influenced the Ottnangian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

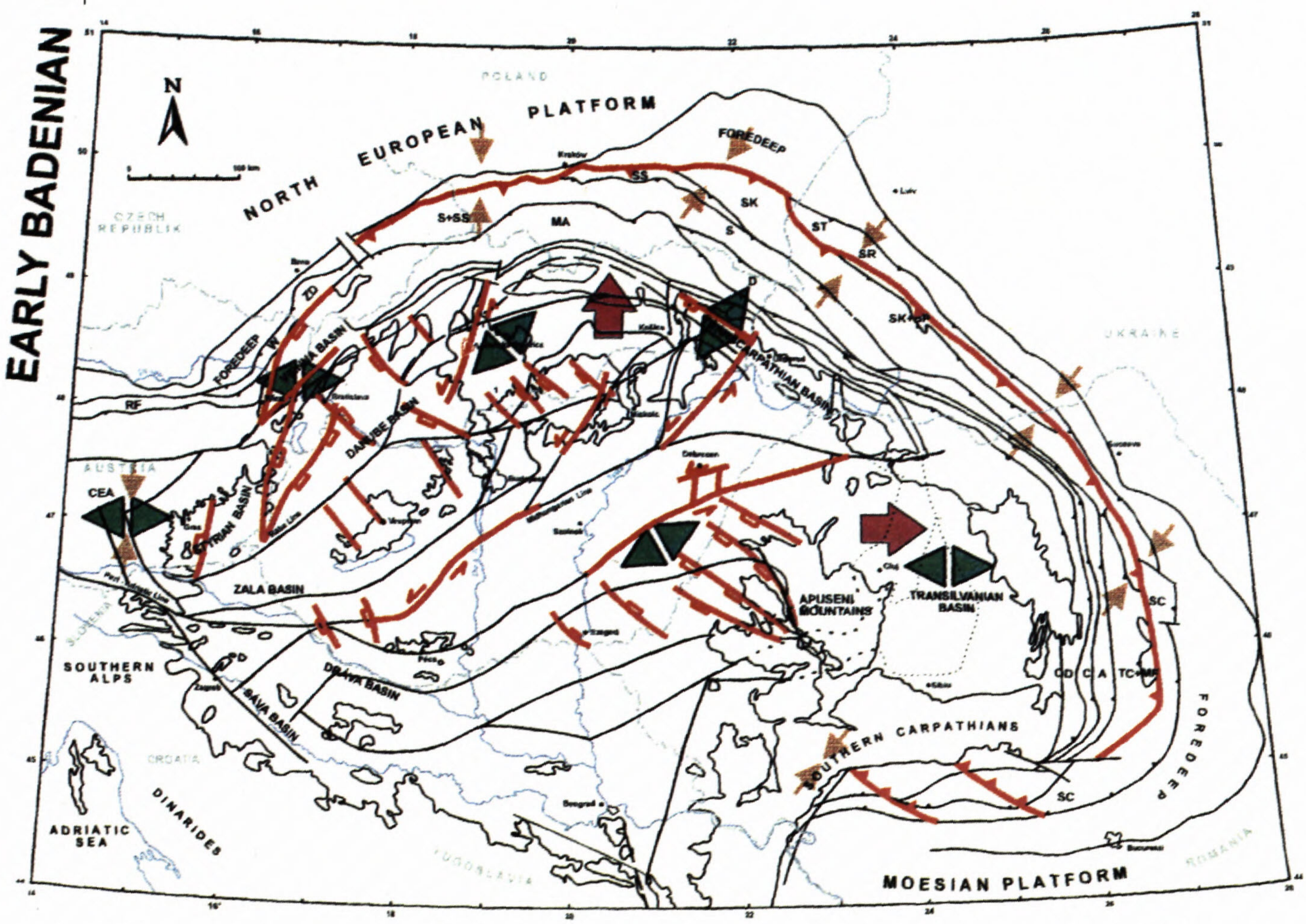


Fig. 5 Major tectonic elements which influenced the Early Badenian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

The stretching of the TISZA - DACIA unit in the Great Hungarian Plain and Transylvanian Basin, where the E - W oriented extension was documented (Csontos and Horváth 1995, Huismans et al. 1997), was induced by the accelerated subduction in the Eastern Carpathian front during the Intra Badenian phase (Micu 1990). We presuppose, that the extension in the Great Hungarian plain basement and the Transylvanian Basin was compensated by a slight clockwise rotation of eastern part of the microplate during this time. This idea is supported also by the Early Badenian tectonic pattern, with NE - SW to ENE -WSW oriented sinistral strike slips along the Mid Hungarian line and by the Early Badenian NW - SE stretching compressive structures and folds in the Getic depression (Matenco 1997).

The Late Sarmatian-Early Pannonian counter clockwise rotation of the Transcarpathian subunit accompanied by slight clockwise rotation of the Dacia subunit

The Late Badenian and Sarmatian evolution of the Carpathians was controlled by compression in front of the orogen (subduction), which led to the accretion of the Skola - Skiba - Tarcau and Borislav - Pokuty - Marginal Folds nappe pile at the active front of the Carpathians, thrusted over the Sambor - Rozniatov and Subcarpathian Neogene units (Oszczypko and Slaczka 1989, Micu 1990).

The subsurface load of the downgoing slab (Krzywiec and Jochim 1997) accelerated the foredeep subsidence before the front of the Carpathians (Kováč et al. in press.). At the end of the Badenian the Skola and Borislav - Pokuty units (in this time acting as a homogenous sheet) were thrusted over the Sambor - Rozniatov unit. It is important to note, that the last thrust of the Outer Western Carpathian front over the foredeep took place after the Early Sarmatian (Oszczypko and Slaczka 1989).

This process was followed by the subduction retreat in front of the Eastern Carpathians, where the accelerated thrust tectonics started during the Early Sarmatian. The Intra Sarmatian - Moldavian tectonic phase was accompanied by large overthrust of the Tarcau and Marginal Folds Nappes (in this time acting as a homogenous sheet) over the Subcarpathian Neogene unit, but the thrust of the Subcarpathian unit over the foredeep lasted till the end of the Pannonian (Sandulescu 1988, Micu 1990).

The Sarmatian thrust tectonic in the Outer Moldavides shows a radial pattern of the paleostress field, with NE - SW oriented compression in the northeast, with E - W

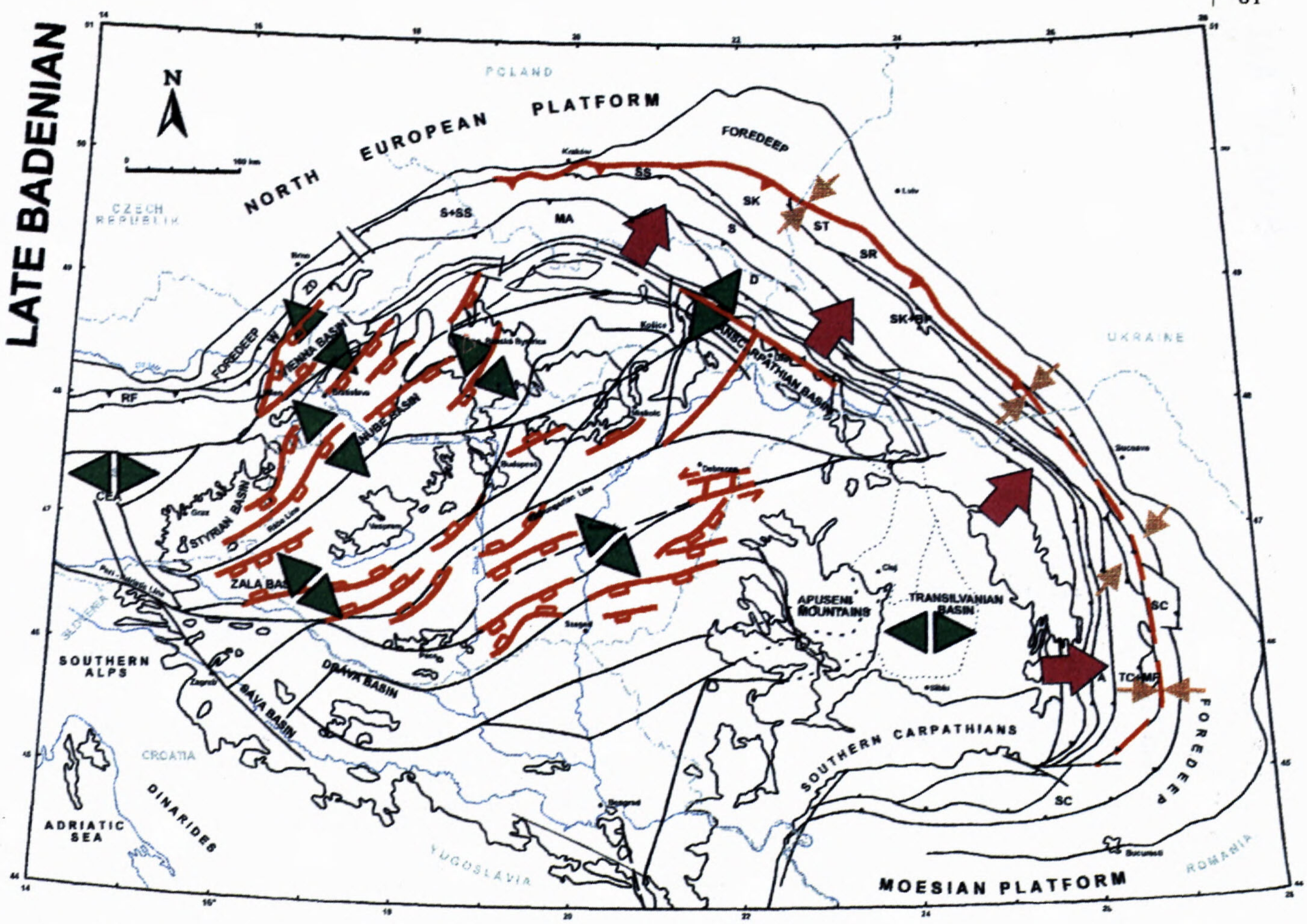


Fig. 6 Major tectonic elements which influenced the Late Badenian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

oriented compression in the east and with NW - SE oriented compression in the south (Matenco 1997).

The Late Badenian back arc extension was associated with updoming of the mantle masses accompanied by the areal type calc - alkaline volcanism (Pécskay et al. 1995). Meanwhile the volcanic chain in the hinterland of the Eastern Carpathians reached a character of island arc type volcanites during the Late Badenian and Sarmatian (Lexa et al. 1993).

It is important to note that the extension in the Pannonian Basin System during the Late Badenian shows different structural patterns in the east and in the west (Fig. 6).

In the western part of the Pannonian Basin System a NW - SE oriented extension controlled the function of NE - SW to NNE - SSW oriented normal and listric faults in the Danube Basin and intramontane basins of the Western Carpathians (Nemčok and Lexa 1990, Kováč et al. 1997). Very similar structural pattern can be observed along the western part of the Mid Hungarian line and in the Great Hungarian Plain (Csontos 1995).

In the east, a NE - SW to E - W oriented extension dominated in the Transcarpathian and Transylvanian Basins (Kováč et al. 1995, Huismans et al. 1997).

During the Early Sarmatian the structural pattern changes in the Carpatho - Pannonian region (Fig.7). In the northern and central part of the Western Carpathians a slight NE - SW oriented compression activated the ENE - WSW oriented sinistral strike slips during the active elongation of the Western Carpathians (Hók et al. 1995, Kováč et al. 1997). But the documented Early Sarmatian paleostress field with E - W oriented compression was followed by NW - SE oriented extension in the NW part of the Transcarpathian depression, i.e. in the East Slovakian Basin (Kováč et al. 1994, 1995).

In the TISZA - DACIA superunit the Sarmatian uplift led to ceasing of sedimentation in the Great Hungarian Plain (Meulenkamp et al. 1996). In the Transylvanian Basin the Sarmatian E - W extension (Huismans et al. 1997) was followed by NE - SW contraction (Matenco 1997).

Summarizing the above discussed facts, we infer that the rotation of the Transcarpathian depression basement took place due to Early Sarmatian subduction pull in the Western to Eastern Carpathians junction followed by the Late Sarmatian to Early Pannonian push of the slightly clockwise rotating eastern part of the Tisza-Dacia microplate, which was in this time influenced by the pull of the subduction in the southern part of the Eastern Carpathians.

The main tectonic structures accommodating the counter clockwise rotation of the Transcarpathian subunit were the NW - SE trending sinistral strike slips and the ENE - VSW to NE - SW oriented normal faults active

SARMATIAN

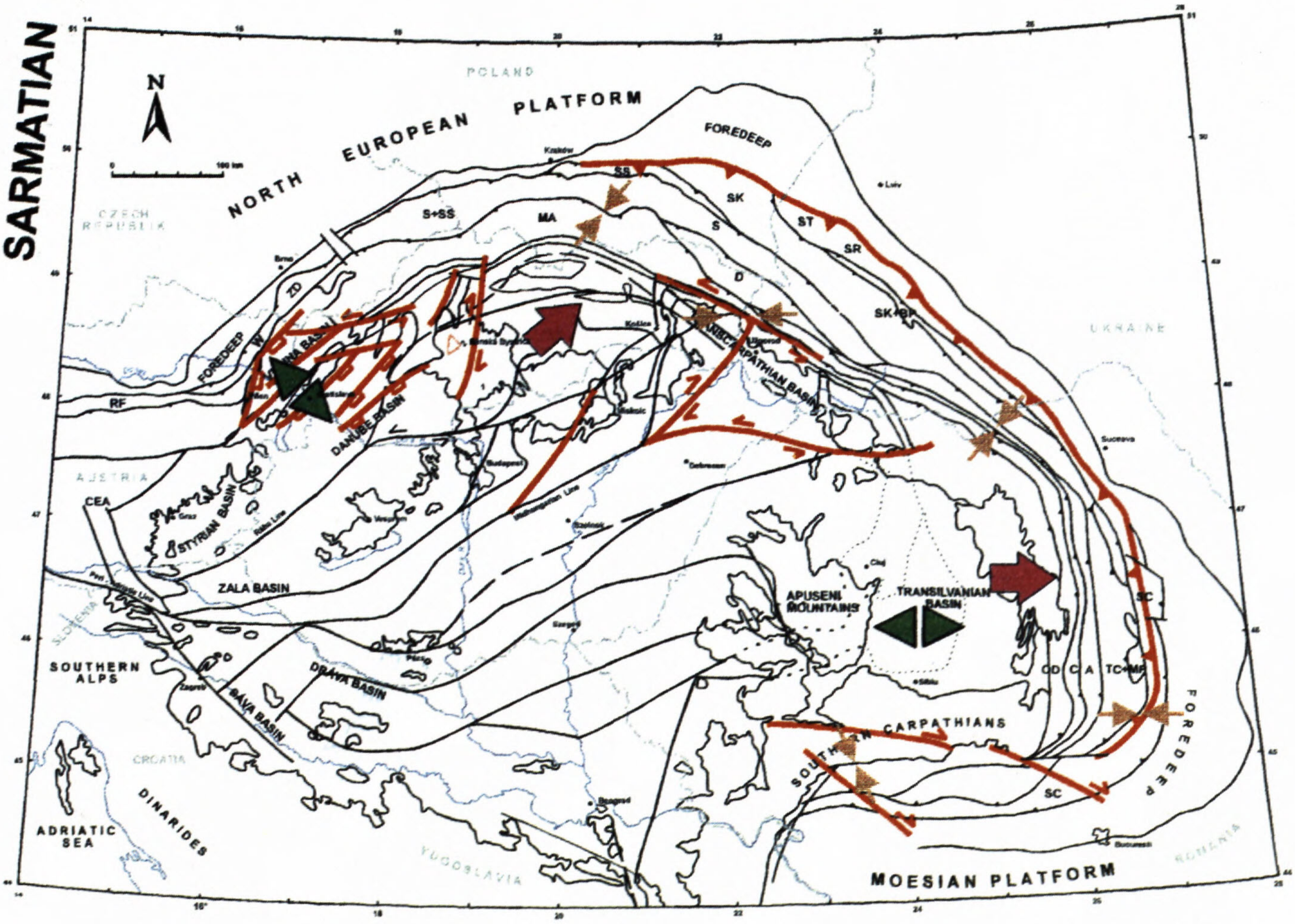


Fig. 7 Major tectonic elements which influenced the Sarmatian evolution of the Carpatho-Pannonian region (explanation see Fig. 8)

in NW - SE oriented extension in the Transcarpathian depression during the Late Sarmatian and Early Pannonian.

It seems that the counter clockwise rotation of the Transcarpathian subunit is contemporaneous with an Early Pannonian compressive event in the western part of the Intra Carpathian region (Fig.8): the change of paleostress field from NW - SE extension to NE - SW compression in the East Slovakian Basin occurs when the NW - SE oriented extension changes to N - S compression in the Central Western Carpathians (Hók et al. 1995, Kováč et al. 1994, 1995).

Following the above mentioned N - S oriented compression in the Central Western Carpathians we can observe the structural pattern formed by the same paleostress field in the Transdanubian Central range, Sava fold zone or Mecsek Mts., where E -W to NE - SW oriented folds and thrust are reported (Csontos et al. 1991, Csontos and Horváth 1995) and can be considered also as the compensation structures to the youngest rotation of the Intra Carpathian region.

The whole picture can be completed by E - W compression in the Eastern Alps (Pereson and Decker 1997) and E-W contraction in the Transylvanian Basin (Huismans et al. 1997).

The Upper Miocene period in the Carpatho - Pannonian region started with above mentioned slight rifting phase and was followed by large postrift thermal subsidence in the Pannonian back arc domain. Active subduction retreat is documented only in the southern part of the Eastern Carpathians. So far no paleomagnetic rotation was documented during this period.

Conclusions

The results of palinspastic reconstruction of the Carpatho - Pannonian region evolution during the Miocene, together with paleomagnetic investigations indicate:

- the large rotation of the TISZA - DACIA microplate must have taken place partly before and partly after the Early Miocene (Eggenburgian excluded)
- the large Early Miocene (Ottnangian) counter clockwise rotation of the ALCAPA microplate (40°-50°) was generated mainly by the Western Carpathians subduction pull
- the Early Badenian counter clockwise rotation (20° - 30°) of the Western Carpathians, the Pelso (and the northwestern part of the Tisza subunit) was due to the Western Carpathian subduction pull compensated by the initial rifting in back arc basin area

PANNONIAN

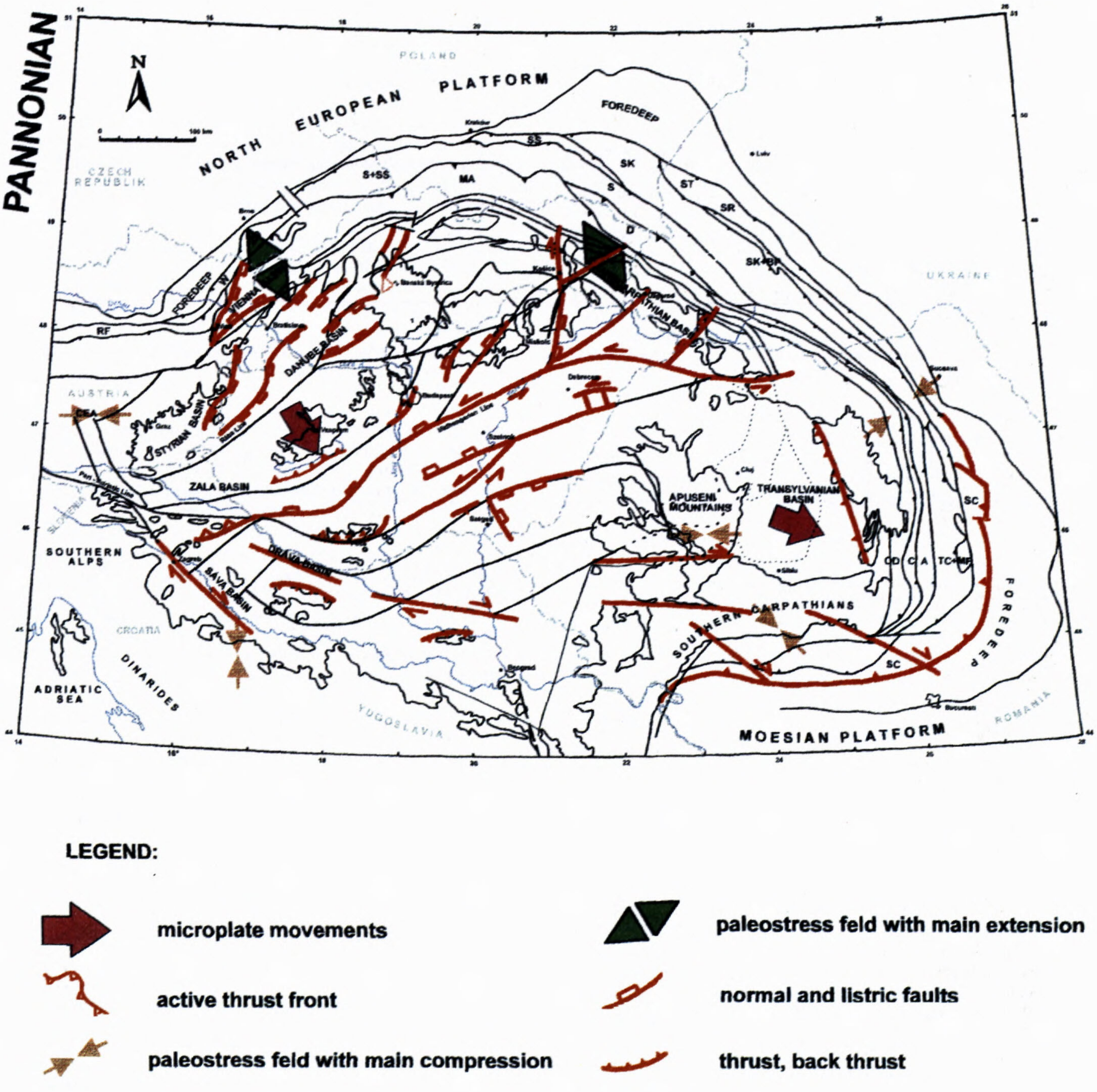


Fig. 8 Major tectonic elements which influenced the Pannonian evolution of the Carpatho-Pannonian region

- the palinspastic reconstruction requires a Badenian to Sarmatian slight clockwise rotation of the Apuseni Mts. and Dacides, due to the updoming of mantle masses in the back arc basin and the subduction retreat in Eastern Carpathians
- the Late Sarmatian-early Pannonian counter clockwise rotation (30° - 40°) of the Transcarpathian subunit reflects the last Western Carpathians overthrust in the north and twisting of the TISZA - DACIA superunit in the south
- In the Eggenburgian through Early Pannonian time period compressive, extensive and rotational events are recognized to have occured three times, always in the same order.

Acknowledgement

We acknowledge the financial suport from VEGA grant 1305296, OTKA research grant T017008 and the scientific discussions with L. Csontos, A. Nagymarosy, N. Oszczypko, D. Plašienka and A. Slaczka.

References

Balla, Z. 1984: The Carpathian loop and the Pannonian basin: a kinematic analysis. Geophys. Trans., 30, 4, 313-353.

Birkenmajer, K. 1986: Stages of structural evolution of the Pieniny Klippen Belt, Carpathians. Stud. Geol. Pol., 88, 7-32.

Csontos, L. 1995: Tertiary tectonic evolution of the Intra Carpathian area: a review. Acta Vulcanologica, 7, 1-13.

Csontos, L. and Horváth, F. 1995: Tertiary structural evolution of the intra-carpathian area: A report on integrated basin studies, Pannonian Basin E.C. Project. Geol. Soc. Greece, Sp. Publ., 4, 12-17.

Csontos, L., Nagymarosy A., Horváth, F. and Kováč, M. 1992: Tertiary evolution of the intra-Carpathian area: a model. Tectonophysics, 208, 221-241.

Csontos, L., Tari, G., Bergerat, F. and Fodor, L. 1991: Evolution of the Stress fields in the Carpatho- Pannonian area during the Neogene. Tectonophysics, 199, 73-91.

Fodor, L. 1995: From transpression to transtension: Oligocene-Miocene structural evolution of the Vienna Basin and East Alpine - Western Carpathian junction. Tectonophysics 242, 151-182.

Fodor, L., Magyari, A., Kázmér, M. and Forarasi, A. 1992: Gravity-flow dominated sedimentation on the Buda paleoslope (Hungary): Record of Late Eocene continental escape of the Bakony unit. Geol. Rundschau, 81, 3, 659-716.

Fuchs, W. 1984: Grosstektonische Neuorientirung in der Ostalpen und Westkarpaten unter Einbeziehung plattentektonischer Gesichtspunkte. J. Geol. Bundesanstalt, 127, 571-631.

Hók, J., Šimon, L., Kováč, P., Elečko, M., Vass, D., Halmo, J. and Verbich, F. 1995: Tectonics of the Hornonitrianska kotlina depression in the Neogene. Geol. Carpath., 46, 4, 191-196.

Horváth, F. 1993: Towards a mechanical model for the formation of the Pannonian basin. Tectonophysics 226, 333-357.

Huismans, R. S., Bertotti, G., Ciulavu, D., Sanders, C.A.E., Cloetingh, S. and Dinu, C. 1997: Structural evolution of the Transylvanian Basin (Romania): a sedimentary basin in the bend zone of the Carpathians. Tectonophysics, 272, 249-268.

Kázmér, M. 1986: Tectonic units of Hungary: Their boundaries and stratigraphy. Ann. Univ. Sci. Budapest, Sect. Geol., 26, 71-84.

Kázmér, M. and Kovács, S. 1985: Permian-Paleogene paleogeography along the Eastern part of the Insubric-Periadriatic Lineament system: evidence for continental escape of the Bakony-Drauzug Unit. Acta. Geol. Hung., 28, 71-84.

Kováč, M. and Túnyi, I. 1995. Interpretation of the paleomagnetic data from western part of the Central Western Carpathians. Mineralia slov., 27, 213-220.

Kováč, M., Baráth, I. and Nagymarosy, A. 1997: The Miocene collapse of the Alpine - Carpathian - Pannonian junction: an overview. Acta Geologica Hungarica, 40. 3, 241-264.

Kováč, M., Cicha, I., Krystek, I., Slaczka, A., Stránik, Z., Oszczypko, N. and Vass, D. 1989: Palinspastic Maps of the Western Carpathian Neogene 1:1000 000. Geol.survey Prague, 31p.

Kováč, M., Csontos, L., Nagymarosy, A., Oszczypko, N., Slaczka, A. Balintoni, I., Marunteanu, M. and Márton, E. 1998: Palinspastic reconstructions of the Carpatho - Pannonian region development during the Neogene. In Rakús, M. ed.: Geodynamical model of the Western Carpathians evolution. Slovak Geol. Surv., Bratislava, in press.

Kováč, M., Kováč, P., Marko, M., Karoli, S. and Janočko, J. 1995: The East Slovakian Basin - A complex back-arc basin. Tectonophysics 252, 453-466.

Kováč, M., Kráľ, J., Márton, E., Plašienka, D. and Uher, P. 1994: Alpine uplift history of the Central Western carpathians: geochronological, paleomagnetic, sedimentary and structural data. Geologica Carpathica, 45, 2, 83-96.

Kováč, P. and Hók, J. 1993: The Central Slovak Fault System - field evidence of a strike-slip. Geol. Carpathica, 44, 155-160.

Kováč, P., Vass, D., Janocko, J., Karoli, S. and Kalinciak, M. 1994: Tectonic history of the East Slovakian Basin during the Neogene. ESRI occasional publ., 11A: Slovakian Geology, 1-14.

Krzywiec, P. and Jochim, P. 1997: Characteristic of the Miocene subduction zone of the Polish Carpathians: results of flexural modelling. Przeglad Geol., 45, 8, 785-792.

Lexa, J., Konečný, V., Kaličiak, M. and Hojstričová, V. 1993: Distribúcia vulkanitov karpatsko-panónskeho regiónu v priestore a čase. In Rakús, M. and Vozár, J. eds.: Geodynamický model a hlbinná stavba Západných Karpát. GUDŠ Bratislava, 57-69.

Márton, E. 1986: Paleomagnetism of igneous rocks from the Velence Hills and Mecsek Mountains. Geophys. Transactions, 32, 83-145.

Márton, E. and Fodor, L. 1995: Combination of paleomagnetic and stress data - a case study from North Hungary. Tectonophysics, 242, 99-114.

Márton, E. and Márton, P. 1996: Large scale rotations in North Hungary during the Neogene as indicated by paleomagnetic data. Morris, A. and Tarling, D. H. eds.: Paleomagnetism and Tectonics of the Mediterranean Region. Geol. Soc. Special Publications, N.105, 153-173.

Márton, E., Vass, D. and Túnyi, I. 1995: Early Tertiary rotations of the Pelso megaunit and neighbouring Central West Carpathians. In Hamršníd, E. eds.: New results in Tertiary of West Carpathians II. MND Hodonín, KZPN 16, 97-108.

Matenco, L. C. 1997: Tectonic evolution of the outer Romanian Carpathians. The Netherlands Research School of Sedimentology (NSG) publ. 97O148, 160p.

Meulenkamp, J. E., Kováč, M. and Cicha, I. 1996: On Late Oligocene to Pliocene depocentre migrations and the evolution of the Carpathian - Pannonian system. Tectonophysics, 266, 301-317.

Micu, M. C. 1990: Neogene geodynamic history of the Eastern Carpathians. Geol. Zbor., Geol. Carpath., 41, 1, Bratislava, 59-64.

Mišík, M. 1997: The Slovak part of the Pieniny Klippen Belt after the pioneering works of D. Andrusov. Geol. Carpath. 48, 4, 209-220.

Morley, C. K. 1996: Models for relative motion of crustal blocks within the Carpathian region, based on restorations of the outer Carpathian thrust sheets. Tectonics, 15, 4, 885-904.

Nagymarosy, A. and Báldi-Béke, M. 1993: The Szolnok unit and its probable paleogeographic position. Tectonophysics 225, 457-470.

Nemčok, M. and Lexa, J. 1990: Evolution of the basin and range structure around Žiar mountain range. Geol. Zbor. geol. Carpath., 41, 229-258.

Oszczypko, N. and Slaczka, A. 1989: The evolution of the Miocene basins in the Polish Flysch Carpathians and their foreland. Geol. Zbor., Geol. Carpath., 40,1, 23-36.

Patrascu, St., Bleahu, M. and Panaiotu, C. 1990: Tectonic implications of paleomagnetic research into Upper Cretaceous magmatic rocks in the Apuseni Mountains, Romania, Tectonophysics, 180, 309-322.

Patrascu, St., Panaiotu, C., Seclaman, M. and Panaiotu, C. E. 1994: Timing of rotational motion of Apuseni Mountains (Romania): paleomagnetic data from Tertiary magmatic rocks. Tectonophysic, 233, 163-176.

Pécskay, Z., Lexa, J., Szakács, A., Kad. Balogh, I., Seghedi, I., Konečný, V., Kovács, M., Márton, E., Kalinčiak, M., Széky - Fux, V., Póka, T., Gyarmati, P., Edelstein, O., Rosu, E. and Žec, B. 1995: Space and time distribution of Neogene and Quarternary volcanism in the Carpatho-Pannonian Region. Acta Volcanologica, 7, 15-28.

Peresson, H.and, Decker, K. 1997: The Tertiary dymics of the northern Easter Alps (Austria) : changing paleostresses in a collisional plate boundary. Tectonophysics 272,125-157.

Plašienka, D. Putiš, M., Kováč, M. Šefara, J. and Hrušecký, I. 1998: Zones of Alpidic subduction and crustal underthrusting in the Western Carpathians. In Grecula, P. ed.: Pre-Alpine and Alpine tectonometamorphic and magmatic evolution of the Western Carpathians, Slovak Geol. Survey., in press.

Plašienka, D., Soták, J. and Prokešová, R. 1988: Structural profiles across the Šambron - Kamenica Periklippen belt zone of the Central Carpathian Paleogene Basin in NE Slovakia. Mineralia slov., 29, 1, in press.

Ratschbacher, L., Frisch, W., Linzer, G.H. and Merle, O. 1991: Lateral extrusion in the Eastern Alps, Part 2. Structural analysis. Tectonics, 10, 257-271.

Ratschbacher, L., Frisch, W., Neubauer, F., Schmid, S. M. and Neugebauer, J. 1989: Extension in compressional orogenic belts: The Eastern Alps. Geology, 17, 404-407.

Ratschbacher, L., Linzer, H. G., Moser, F., Strusievicz, R. O., Beddelean, H., Har, N. and Mogos, P. A. 1993: Cretaceous to Miocene thrusting and wrenching along the Central South Carpathians due to a corner effect during collision and orocline formation. Tectonics, 12, 4, 855-873.

Rögl, F. and Steininger, F.F. 1983: Vom Zerfall der Tethys zu Mediterran and Paratethys. Ann. Naturhist. Mus. Wien, 85/A, 135-163.

Roth, Z. 1980: The Western Carpathians -a Tertiary structure of the Central Europe. Knihovňa UUG, 55, Geol. survey Prague, 1-128 (In Czech with English Summary).

Royden, L. 1993: The tectonic extension slab pull at continental convergent boundaries. Tectonics, 12, 2, 303-325.

Sandulescu, M. 1988: Cenozoic Tectonic History of the Carpathians. In Royden, L. H. and Horváth, F. (eds.): The Pannonian Basin, a study in basin evolution. AAPG Memoir 45, 17-25.

Soták, J., Michalík, J., Reháková, D. and Hamršmíd, B. 1997: Paleogene sediments below the base of a Mesozoic nappe in the Humenské vrchy Mts. (Podskala borehole): Stratigraphic constrains for Tertiary thrust tectonics. Geol. Carpathica, 48, 3, 193-203.

Soták, J., Spišiak, J. and Biroň, A. 1994: Metamorphic sequences with "Bundnerschiefer" lithology in the pre Neogene basemnt of the East Slovakian Basin. Mitt. Osterr. Geol. Gesel., 111-120.

Steininger, F.F., Senes, J., Kleemann, K. and Rögl, F. 1985: Neogene of the Mediterranean Tethys and Paratethys. Vol. 2, 2-534.

Szabó, C., Harangi, Sz. and Csontos, L. 1992: Review of Neogene and Quaternary volcanism of the Carpathian - Pannonian region. Tectonophysics 208, 243-256.

Sztano, O. 1994: The tide-influenced Pétervására sandstone, Early Miocene, Northern Hungary: sedimentology, paleogeography and basin development. Geologica Ultraiectina 120, Utrecht, 153p.

Túniy, I. and Kováč, M. 1991: Paleomagnetic investigation of the Neogene sediments from the Little Carpathians. Contr. Geophys. Inst. Slov. Acad. Sci., 21, 125-146.

Vass, D., Hók, J., Kováč, P. and Elečko, M. 1993: The Paleogene and Neogene tectonic events of the Southern Slovakia depressions in the light of the stress-field analyses. Mineralia slov., 25, 79-92.

Vörös, A. 1993: Jurassic microplate movements and brachiopod migrations in the western part of the Tethys. Paleogeogr., Paleoclim., Paleoecol., 100, 125-145.

Slovak Geol. Mag. 4, 2(1998), 87–94

Stable Isotope record in Miocene Fossils and Sediments from Rohožník (Vienna Basin, Slovakia)

ŠÁRKA HLADILOVÁ[1], JANA HLADÍKOVÁ[2] & MICHAL KOVÁČ[3]

[1] Department of Geology and Paleontology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
[2] Czech Geological Survey, Klárov 3, 118 21 Praha 1, Czech Republic
[3] Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovak Republic

Abstract: Results of stable isotope analyses of Miocene (Badenian, Sarmatian) molluscs and sediments from the localities Rohožník - Vajarská and Rohožník - Konopiská are presented and used for interpretations of Miocene depositional as well as diagenetic conditions in this part of the Vienna Basin.

Key words: Miocene, Vienna Basin, Molluscs, Stable Isotopes

1. Geological setting, Regional Geology and Palaeontology

The locality Rohožník is situated (Fig. 1, 2) in the eastern part of the Vienna Basin and on the western edge of Malé Karpaty Mts., 14 km NE. from the town of Malacky (Slovakia).

The pre-Neogene basement in this area is represented by Triassic megabreccia of Wetterstein-type limestones belonging to the uppermost tectonic units (tyrolicum) of the Northern Calcareous Alps.

In the wider surroundings of Rohožník the Miocene sedimentation began in Badenian by faunistic sterile *block and coarse grained conglomerates*. It is a continental facies of debris cones with material from the pre-Neogene basement, e. g. of the Malé Karpaty Mts. provenience. The penetration of the (Upper) Badenian marine transgression is documented by basal conglomerates and sandstones. The petrographic composition of their pebble material corresponds also to the basement, indicating their local origin. The matrix of the conglomerates consists mainly of the organodetritic sandy limestone (detritus of molluscs, algae, moss animals, worms and foraminifers). The matrix as well as the pebbles often bear the boring traces of the bivalves *Lithophaga* sp. and *Gastrochaena* sp. and sponges *Cliona* sp. The sandstones are mostly calcareous, with a changing composition, with abundant molluscs and red algae. The sediments originated in the littoral zone, in the depressions of the underlying rocks, in a good aerated and lighted sea with a high dynamics. In the direction of the depth the amount of organic rests is increasing to the detriment of the terrigenous material.

In the direction of the top the basal clastic sediments are passing into *Leitha (algal) limestones* forming a typical reef complex (Fig. 3). The origin of reefs was related to a tectonically active coastal line influenced by the transtension tectonics of Leitha faults of the NNE-SSW direction with a markedly normal character (Marko et al., 1990). Other algal bioherms were formed also on the basement elevations on the SE margin of the basin in the depths to about 40 m, in the sea with the normal salinity. They are very rich in flora and fauna (red algae, moss animals, corals, foraminifers, worms, echinoids, molluscs). These sediments were accessible until recently in the quarry Rohožník - Vajarská and their detailed paleontological research was made for example by Schaleková (1973, 1978), Mišík (1976), Benejová (1985). Baráth (1992) distinguished 6 microfacial limestone types related to the sedimentation in different hydrodynamic conditions. The facies of algal limestones was relatively stable and it yielded the material also for other laterally substituting facies. The sediments of these facies are accessible at the locality Rohožník- Konopiská, nowadays already an unexploited deposit of the correction clays for the production of portland cement, situated about 1.5 km SW. of the quarry Rohožník - Vajarská. The forereef detritic carbonate facies, which originated as a result of the wave activity, accumulated in the form of reef talus cones on the submerged slopes of the Malé Karpaty Mts. before the frontal part of the reef complex. It has the character of the *coarse-grained breccias* consisting of the detritus of reef limestones, red algae and molluscs. In the direction into the basin, these sediments are finger-like or in the form of lens-like bodies, layers and films of variable thickness reaching - often to a considerable distance - the sediments of the basinal pelitic facies. Hladilová, 1991 found out 15 species of bivalves, 19 species of gastropods and 1 species of scaphopods in

Geological Survey of Slovak Republic, Dionýz Štúr Publishers, Bratislava 1998 ISSN 1335-96X

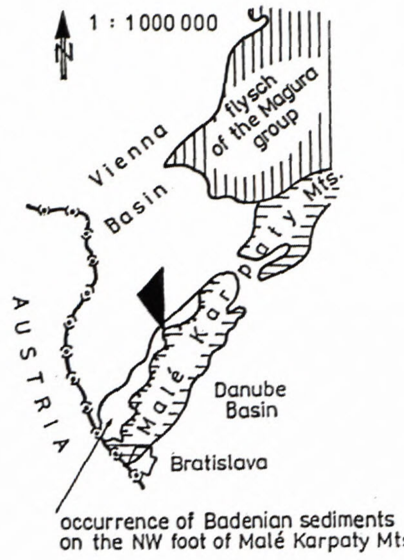


Fig. 1: Simplified geological map of the wider surroundings of Rohožník

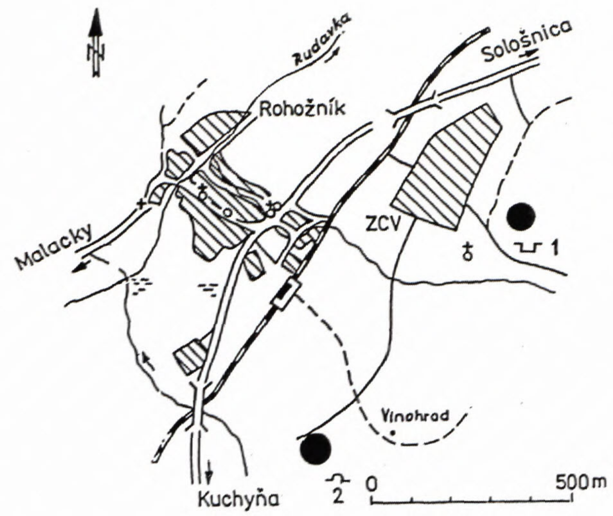


Fig. 2: Sketch map of the vicinity of Rohožník
1 - Rohožník - Vajarská, 2 - Rohožník - Konopiská

these layers. Thick-walled types, considerably damaged (broken, rolled), are prevailing.

The sediments of the basinal facies are represented by the greenish to bluish dark-grey *calcareous clays* with changing contents of organic matter and pyrite. Clays are mostly homogeneous, only in places a slight lamination characteristic for an anoxic environment without bioturbation can be observed. In places, calcareous and gypsum concretions appear in these sediments. In clays, rich assemblages of foraminifers, ostracods, calcareous nannoplankton and fish otoliths were found out (Čierna, 1973, Kučerová, 1982, 1984, 1986, Pachón Duarte, 1989, Horák, 1985, Holec, 1973, 1975, 1978). The molluscan community (Hladilová, 1991) is poor in species and rich in individuals, with a significant predominance of the species *Corbula gibba* and *Hinia illovensis*. Fossil traces *Oichnus paraboloides* and *Entobia* ichnosp. can be often found on the molluscan shells (Pek, Mikuláš & Lysáková, 1997). Together with the sediment character it bears witness of occasional worsening of the environmental conditions near to the bottom of the basin, probably as a result of the lowering of water dynamics and O_2 contents (episodically worse aeration).

The upper part of the profile at the locality Rohožník-Konopiská is formed of *sandy clays to sands* with frequent oblique, cross and ripple-drift bedding (Upper Badenian/Sarmatian). In these sediments abundant fossils of molluscs with prevailing pirenells and ervilias were found out (Hladilová, 1991). Except of molluscs benthic foraminifers and poor assemblages of calcareous nannoplankton occur in sands (Šutovská, oral communication, 1988). Paleontological analyses indicate a salinity decrease as well as the growing of water dynamics of the marine environment, e. g. an isolation and a significant shallowing of the basin with a mixing of the elements from the phytal and aphytal infra- and circalittoral. The shells often carry signs of transport and rolling, some fossils are redeposited from older sediments.

2. Methods

2.1 Sampling

For stable isotope analyses following components were collected from the site Rohožník - Konopiská and Rohožník - Vajarská:

A) fossil shells of molluscs from various facies:
- facies of algal limestones - *Venus* sp. (locality Rohožník - Vajarská)
- facies of coarse-grained forereef sands - *Ostrea digitalina*, *Glycymeris* sp., *Lunatia catena helicina*, *Ancilla glandiformis*, *Venus multilamella*, *Turritella* cf. *erronea*, *Conus dujardini* (locality Rohožník - Konopiská)
- facies of calcareous clays - *Corbula gibba*, *Lunatia catena helicina*, *Vermetus intortus* (Locality Rohožník - Konopiská)
- facies of sandy clays to sands - *Corbula gibba*, *Clithon pictus*, *Pirenella picta*, *Vermetus intortus*, *Lunatia catena helicina*, *Turritella* cf. *erronea*, *Conus* sp., *Bittium reticulatum*, *Acteocina lajonkaireana*, *Cerithium* cf. *politioanei* (locality Rohožník - Konopiská)

B) sediments containing carbonate and organic matter:
- algal limestones (Rohožník - Vajarská, pebbles of the algal limestones from the coarse-grained forereef sands - Rohožník - Konopiská)
- calcareous clays - Rohožník - Konopiská
- sandy clays to sands - Rohožník - Konopiská

C) carbonate concretions from the calcareous clays (Rohožník - Konopiská):
- gypsum concretion („gypsum rose") from the calcareous clays (Rohožník - Konopiská)

2.2 Isotopic methods

2.2.1 Isotopic analysis of carbonate

For carbon and oxygen isotopic analysis calcium carbonate samples were decomposed in vacuum by 100 %

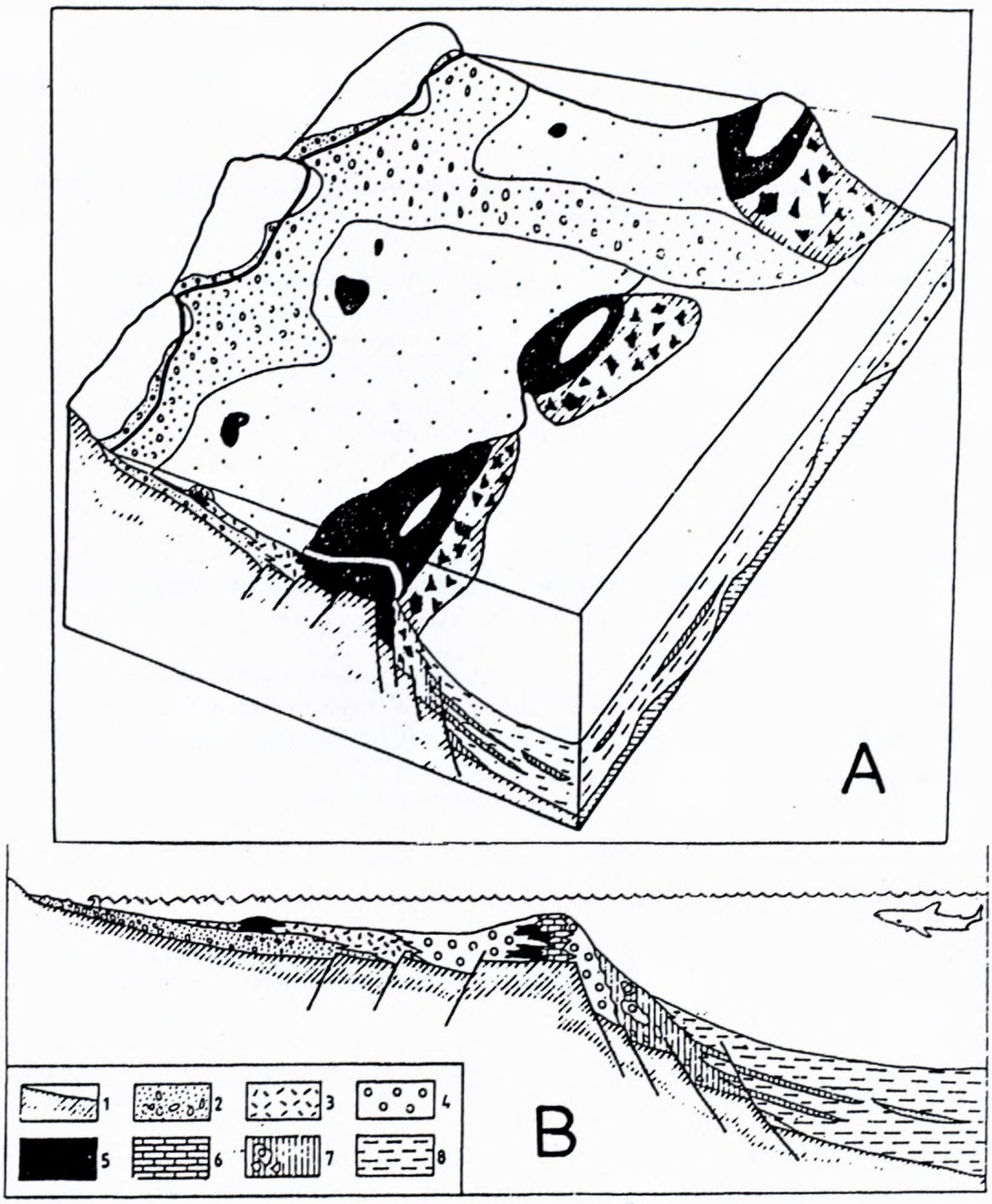


Fig. 3: A - Rohožník - reconstruction of the reef complex (after Baráth, 1992)
B - Rohožník - a schematic profile through the reef complex. 1 - pre-Neogene basement, 2 - basal rudstone, 3 - algal - foraminiferal wackstone, 4 - rhodolith bafflestone, 5 - algal - bryozoan and algal - coral bindstone, 6 - biodetritic rudstone, 7 - forereef coarse-detrital rudstone to grainstone, 8 - basinal mud facies. After Kováč et al., 1991 and Baráth, 1992.

H_3PO_4 at 25 °C (McCrea, 1950). Released CO_2 was analysed on the Finnigan MAT 251 mass - spectrometer. The results are reported in per mil deviation from V-PDB standard using δ notation. The precision of both carbon and oxygen isotope analyses is better than ±0.1 ‰. Corrections for aragonite were carried out.

2.2.2 Isotopic analysis of organic carbon

For mass-spectrometric analyses carbonates from samples were removed by hot diluted phosphoric acid. The residue after washing and drying was oxidized in flow of oxygen at 950 °C. Formed carbon monoxide was decomposed by CuO at 900 °C, compounds of chlorine and sulphur were reacted with silver wool, water formed during oxidation was frozen. Nitrogen oxides which were very often formed were reduced by hot copper to N_2. Isotope measurements of pure carbon dioxide were performed by mass - spectrometer Finnigan MAT 251. The δ values were defined as the per mil deviation from V-PDB standard. The reproducibility was ± 0.1 ‰.

2.2.3 Isotopic composition of sulphur in sulphate

Gypsum was dissolved in hot distilled water and precipitated from water as $BaSO_4$. For isotopic measurement

$BaSO_4$ was converted to SO_2 in a vacuum line using the method of Yanagisawa & Sakai, 1983. $BaSO_4$ was mixed with V_2O_5 and SiO_2 (weight ratio of 1:10:10), heated to 980 °C over a period of 10 min and kept for another 10 min. SO_2 was trapped in a glass ampoule by liquid nitrogen and sealed. All $\delta^{34}S$ analyses were performed on a Finnigan MAT 251 mass spectrometer with reproducibility of 0.2 ‰. The results were expressed in the usual δ notation as a per mil deviation of the $^{34}S/^{32}S$ ratio in sample from the CDT standard.

2.2.4 Isotopic composition of oxygen in sulphate

$BaSO_4$ with pure graphite in platinum foil was decomposed in vacuum line at about 1000 °C. Carbon monoxide which was produced during reaction was converted to carbon dioxide by a high voltage transformer connected to platinum electrodes (Šmejkal & Hladíková, 1987). CO_2 was trapped by liquid nitrogen and its isotopic composition was measured on a Finnigan MAT 251 mass spectrometer with reproducibility of 0.2 ‰. The results were expressed in the usual δ notation as a per mil deviation of the $^{18}O/^{16}O$ ratio in sample from the V-SMOW standard.

3. Results and discussion

3.1 Fossil shells of molluscs

The list and isotopic compositions of bivalves and gastropods selected for isotopic studies are in Table 1. All studied molluscs secreted aragonite shells, only shells of *Ostrea digitalina* are formed by calcite. It was found that the studied shells preserved their primary mineralogy. According to Brand, 1981 the preservation of metastable aragonite has been used to infer that the isotopic composition of the component must be also primary. In addition, gastropods precipitate shell carbonate in isotopic equilibrium with their ambient seawater and exert only minimal „vital effects" (Milliman, 1974). For these reasons isotopic composition of studied aragonite shells can reflect the isotopic composition of the Neogene seawater.

According to paleontological studies the molluscs lived under different conditions - in a deeper seawater, in a shallower seawater and in a brackish water. Oxygen isotopic compositions of their shells should reflect these different environments.

Molluscs living under normal marine conditions in shallow water (from coarse-grained forereef sands) show $\delta^{13}C$ values from -1.0 to 1.2 ‰ and $\delta^{18}O$ values from -1.0 to 2.3 ‰ and average $\delta^{18}O$ value makes 0.4 ‰ (Table 1, facies 1). According to Savin, 1977 the Miocene ocean water was depleted in $\delta^{18}O$ in comparison with present ocean water. Assuming that the seawater had $\delta^{18}O$ value -1 ‰ in this area and using Craig's, 1965 paleotemperature equation we obtained the average temperature of 11 °C as a temperature of water in which this group of molluscs lived. It is necessary to mean that the highest isotopic temperature (17 °C) was calculated for *Conus dujardini* and the lowest isotopic temperature (about 2 °C) was calculated for *Lunatia catena helicina* (sample 3). However, according to palynology, subtropical climate existed during Lower and Middle Badenian in the mentioned area, therefore temperatures of about 11 °C (even 2 °C) are too low. In addition, the difference 15 °C between the highest and the lowest temperatures is too big for subtropical climate. There are at least two possibilities how to explain the mentioned discrepancies.

The first one: the $\delta^{18}O$ value of water in the Badenian sea could be higher than -1 ‰ SMOW, i.e. the $\delta^{18}O$ value which was postulated by Savin, 1977 for ocean water. It is well known, that $\delta^{18}O$ value of the recent ocean water is 0 ‰, whereas the $\delta^{18}O$ value of water in the Mediterranean Sea is +1‰, the $\delta^{18}O$ value of water with higher salinity in Red Sea is 2 ‰ and $\delta^{18}O$ value of water in Black Sea is about -3 ‰ (Anati & Gat, 1989). If we substitute higher $\delta^{18}O$ value for seawater into the paleotemperature equation, then for measured $\delta^{18}O$ values of fossils we obtain higher temperatures. For example, if we take into account the average $\delta^{18}O$ value of fossil shells, i.e. 0.4 ‰ and 0 ‰ for sea water, we obtain temperature of 15 °C.

The second possibility explaining discrepancies in calculated temperatures is the redeposition of shells. For example *Lunatia catena helicina* (Table 1, sample 3) shows $\delta^{18}O$ value which is typical for shells found in facies 2. If this shell was redeposited the difference between the highest and the lowest isotopic temperature calculated for facies 1 would decrease.

The molluscs from the facies 2 (calcareous clays) lived in seawater at a greater depth. They show $\delta^{13}C$ values from -2.7 to -0.6 ‰ (average -1.9 ‰), and $\delta^{18}O$ values from 0.7 to 2.5 ‰ (average 1.9 ‰) (Table 1, facies 2). It is evident that $\delta^{18}O$ values of shells from this group are higher than those from the previous group. If we assume the same $\delta^{18}O$ values of sea water for both marine environments then the molluscs from facies 2 were formed under lower temperature, e. g. in cooler water reflecting the greater depth. The low $\delta^{13}C$ values of fossils from facies 2 demonstrate that molluscs built up CO_2 rich in ^{12}C into their shells. Carbon dioxide rich in ^{12}C is produced during oxidation of organic matter and the consequence of the greater consumption of oxygen for oxidation of organic matter is the lowering of O_2 content in water. The lowering of O_2 content resulted also from the paleontological studies.

The third group of studied molluscs (from sandy clays and sands) lived in brackish environment. In comparison with normal sea water the brackish water is characterized by lower $\delta^{18}O$ values. The $\delta^{18}O$ values of molluscs from facies 3 (Table 1) which are from -3.0 to 0.8 ‰ reflect lower $\delta^{18}O$ values of the brackish water. The $\delta^{13}C$ values of shells from this group are comparable with $\delta^{13}C$ values found for shells formed in normal marine environment. The correlation between $\delta^{13}C$ and $\delta^{18}O$ values of molluscs from brackish environment was not found and therefore it is possible to assume that external contribution of organic matter did not exist.

We also compared $\delta^{18}O$ values of species living in two different environments (for example *Lunatia catena helicina*, *Corbula gibba* and *Vermetus intortus* from fa-

Table 1: Carbon and oxygen isotopic composition of molluscs from Rohožník

sample I.D.	facies	species	carbonate mineralogy	d13C (‰ PDB)	d18O (‰ PDB)	
14	1	*Ostrea digitalina*	calcite	0,3	-0,4	Bivalvia
2b	1	*Venus multilamella*	aragonite	-1,0	1,0	Bivalvia
2c	1	*Glycymeris*sp.	aragonite	0,4	0,0	Bivalvia
7	1	*Turritella* cf. *erronea*	aragonite	1,2	0,4	Gastropoda
9	1	*Conus dujardini*	aragonite	0,9	-1,0	Gastropoda
2a	1	*Ancilla glandiformis*	aragonite	0,2	0,3	Gastropoda
3	1	*Lunatia catena helicina*	aragonite	-0,7	2,3	Gastropoda
1b	2	*Corbula gibba*	aragonite	-2,2	1,9	Bivalvia
13	2	*Corbula gibba*	aragonite	-2,7	2	Bivalvia
13/1	2	*Corbula gibba*	aragonite	-1,5	2,5	Bivalvia
13/2	2	*Corbula gibba*	aragonite	-2,5	1,9	Bivalvia
13/3	2	*Corbula gibba*	aragonite	-2,8	2,4	Bivalvia
4	2	*Vermetus intortus*	aragonite	-0,6	0,7	Gastropoda
1c	2	*Lunatia catena helicina*	aragonite	-1,2	2,1	Gastropoda
1	2	*Lunatia catena helicina*	aragonite	-1,3	1,9	Gastropoda
15	3	*Corbula gibba*	aragonite	-1,1	0,8	Bivalvia
3a	3	*Clithon pictus*	aragonite	1,1	-2,2	Gastropoda
3b	3	*Pirenella picta*	aragonite	-0,5	-3,0	Gastropoda
5	3	*Vermetus intortus*	aragonite	-1,2	-2,2	Gastropoda
2	3	*Lunatia catena helicina*	aragonite	-1,3	-2,4	Gastropoda
6	3	*Turritella* cf. *erronea*	aragonite	1,3	-0,4	Gastropoda
8	3	*Conus* sp.	aragonite	0,1	-1,5	Gastropoda
10	3	*Bittium reticulatum*	aragonite	0,0	-1,3	Gastropoda
11	3	*Acteocina lajonkaireana*	aragonite	-0,6	-2,4	Gastropoda
12	3	*Cerithium* cf. *politioanei*	aragonite	0,1	-1,6	Gastropoda
12/1	3	*Cerithium cf. politioanei*	aragonite	0,1	-1,7	Gastropoda
12/2	3	*Cerithium cf. politioanei*	aragonite	-0,1	-2,0	Gastropoda
12/3	3	*Cerithium cf. politioanei*	aragonite	-0,3	-2,8	Gastropoda

cies 1 and 3, *Turritella* cf. *erronea* from facies 2 and 3 - see Table 1). We can see that their $\delta^{18}O$ values are different reflecting the trend in oxygen isotopic composition of water. All $\delta^{18}O$ values of shells from brackish environment are lower than $\delta^{18}O$ values of shells from marine environments (Fig. 4).

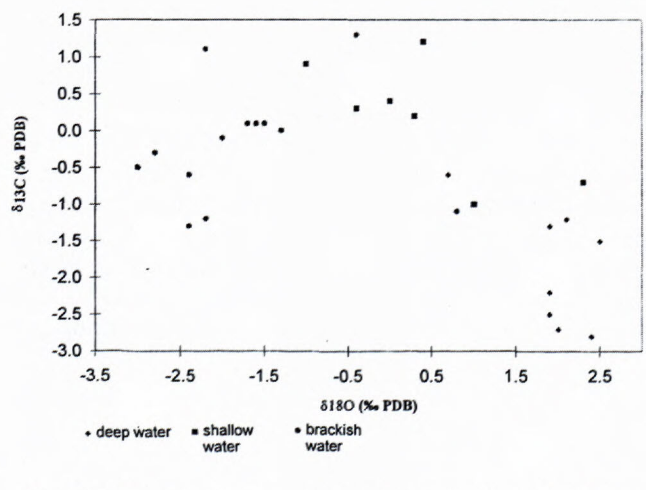


Fig. 4: Carbon and oxygen isotopic composition of molluscs from Rohožník

3.2 Algal limestones

Whole-rock isotopic data clearly reflect all phases of limestone formation. According to Hudson (1977), most calcite cements formed during diagenesis show lower $\delta^{18}O$ and $\delta^{13}C$ values than those of marine carbonate sediments. Carbon and oxygen isotopic data of algal limestones from Rohožník are given in Table 2. It is evident that algal limestones are characterized on one side by very low and on the other side by very high $\delta^{13}C$ values. The $\delta^{13}C$ values from 5.1 to 6.1 ‰ are the highest values from the whole data set. They are higher than $\delta^{13}C$ values given for marine carbonates by Hoefs (1997). The reason for such high $\delta^{13}C$ values is not entirely clear, but Lloyd (1971) suggested that algal photosynthesis consumed ^{12}C isotope from bicarbonate reservoir and residual dissolved bicarbonate - precursor of calcium carbonate - became rich in ^{13}C isotope. So high $\delta^{13}C$ values were found also for the forereef of the Devonian reef in the southern Moravia (Hladíková et al. 1997)

The very low $\delta^{13}C$ values close to -12 ‰ found for algal limestone from Rohožník-Vajarská (Table 2) are typical for carbonates which incorporated oxidized organic carbon.

Table 2: Isotopic composition of sediments

sample I.D.	carbonate $d^{13}C$ (‰ PDB)	carbonate $d^{18}O$ (‰ PDB)	org. matter $d^{13}C$ (‰ PDB)	sulphate $d^{34}S$ (‰ CDT)	sulphate $d^{18}O$ (‰ SMOW)
Rohožník -Vajarská					
algal limestone, sample 1	-12,7	-4,3			
algal limestone sample 2	-11,2	-5,6			
Rohožník - Konopiská					
algal limestone, sample 1a	5,6	-0,3			
algal limestone, sample 1b	5,1	-0,3			
algal limestone, sample 2a	-2,6	-2,6			
algal limestone, sample 2b	-3,7	-2,9			
algal limestone, sample 3	6,1	-2,6			
calcareous clay, sample 1	-0,5	-4,2	-26,4		
calcareous clay, sample 3	-0,6	-5,7	-25,6		
calcareous clay, sample 4	-0,3	-3			
sandy clay, sample 3	-0,9	-6,9			
carbonate concretions					
sample 5a	-44,7	3,1	-30,5		
sample 5b	-49,7	3,4			
gypsum concretion				-7,3	14,2

3.3 Carbonate cements

Isotopic composition of carbonate cements and organic matter from calcareous and sandy clays were determined, results are also in Table 2. The $\delta^{13}C$ values of carbonate carbon are homogeneous from -0.3 to -0.9 ‰ and $\delta^{18}O$ values are -3.0 to -6.9 ‰. Such isotopic compositions could reflect the formation of cements during interaction of carbonates with pore waters. Especially, greater range of $\delta^{18}O$ values can be a result of successive isotopic exchanges between carbonate and water.

The most frequent $\delta^{13}C$ values of total organic matter are from -20 to -30 ‰ (Hoefs 1997). The main cause for mentioned differences in $\delta^{13}C$ values of living organisms are different ways of their biosynthesis and different content of biopolymers: lipids, aminoacids, lignin and polysaccharides (Křibek 1997). A carbon isotopic composition of dissolved bicarbonate in sea water, which is used for photosynthesis, represents another very important factor affecting $\delta^{13}C$ values of organic matter. Popp et al. (1989) found that the carbon isotopic fractionation between marine carbonates and organic matter from Early to Mid-Cenozoic became lower. It is in accordance with $\delta^{13}C$ values of total organic matter from Tertiary marine sediments published by Lewan (1986). $\delta^{13}C$ values for Paleocene - Oligocene are from -32.3 to -25.1 ‰, for Miocene from -21.3 to -23.4 ‰ .

From Rohožník we analysed carbon isotopic composition of organic matter from two samples of calcareous clays and one sample from carbonate concretion. The $\delta^{13}C$ values of total organic matter in calcareous clay are from -25.6 to -26.4 ‰, the $\delta^{13}C$ value for carbonate concretion is -30.5 ‰ (Table 2). The $\delta^{13}C$ values of total organic matter from Rohožník area are lower than those published for Miocene. Regarding the low number of analysed samples and lacks of other supplementary data we can hardly explain why $\delta^{13}C$ values from Rohožník are lower than published data. The lower $\delta^{13}C$ values of dissolved bicarbonate in sea-water, which was indicated also by fossils living in deeper marine environment, could be a possible explanation of the lower $\delta^{13}C$ values of total organic matter.

Extremely low $\delta^{13}C$ values between -44.7 and -49.7 ‰ were found for carbonate concretions. These very low $\delta^{13}C$ values are accompanied by relatively high $\delta^{18}O$ values, i.e. $\delta^{18}O$ values close to 3 ‰ (Table 2). Such very low $\delta^{13}C$ values could not be the result of oxidation of organic matter its $\delta^{13}C$ values being significantly higher (Table 2). We assume that they are the result of oxidation of methane $\delta^{13}C$ values of which are mainly in the range of -40 to -50 ‰ for Neogene of the Vienna Basin (Buzek et al. 1992). Higher $\delta^{18}O$ values of these cements give evidence that methane was oxidized near the surface, where it is possible to expect a higher evaporation and consequently higher $\delta^{18}O$ values of water.

Such reactions are confined to the vicinity of fractured hydrocarbon reservoirs and thus could be a valuable guide to petroleum exploration; but they are not likely to be of great quantitative significance (Hudson 1977). Such studies could provide a valuable tool in petroleum exploration since the Vienna Basin, including the wider surroundings of Rohožník, represents an important oil- and gas- bearing area.

Sulphur and oxygen isotopic compositions of gypsum concretion (so called „gypsum rose") were determined. The average $\delta^{34}S$ value of gypsum concretion is -7.3 ‰ CDT and the average $\delta^{18}O$ value is 14.2 ‰ V-SMOW (Table 2). The $\delta^{34}S$ values of sulphate dissolved in the

Tertiary sea water which could be the source of sulphur for gypsum concretion were in the range from 21.6 to 21.9 ‰ CDT (Claypool et al. 1980). It is clear that marine sulphate could not be the source of sulphur during formation of „gypsum rose". The mentioned sulphate was formed during the oxidation of sulphides which are characterized by negative $\delta^{34}S$ values (Hoefs 1997). The $\delta^{18}O$ value found for gypsum concretion is rather high. Sulphates, which were formed by oxidation of disseminated sulphides by meteoric water, are characterized by the $\delta^{18}O$ values from 0 to -5 ‰ V-SMOW (Šmejkal & Dubánek, 1990). It is necessary to mention that during a slow oxidation of disseminated sulphides under low temperatures first of all H_2SO_3 is formed. The fourth oxygen which is needed for formation of H_2SO_4 is obtained from airy O_2 dissolved in water and its $\delta^{18}O$ value is between 9 and 12 ‰ V-SMOW (Šmejkal & Dubánek, 1990). It is evident that gypsum concretion was formed from water rich in isotope ^{18}O. Waters rich in ^{18}O could be formation waters or strongly evaporated meteoric waters. The $\delta^{18}O$ values of formation waters in Vienna Basin show the great range of $\delta^{18}O$ values, but their highest $\delta^{18}O$ value is 5.6 ‰ V-SMOW (Buzek & Michalíček 1997). Also the positive $\delta^{18}O$ values found for carbonate concretion (Table 2) give evidence that waters rich in isotope ^{18}O were present in the studied sequence of strata.

4. Conclusions

a) Paleoenvironmental changes in Rohožník (mainly changes of water depths and salinity) documented in sedimentological as well as paleontological records are also reflected in isotopic values of individual organisms. The $\delta^{18}O$ values of molluscan shells from brackish environment are generally lower than those from marine environments.

b) Algal limestones from Rohožník - Vajarská show $\delta^{13}C$ values typical for carbonates which incorporated oxidized organic carbon. Some of the $\delta^{13}C$ values of algal limestones from the coarse-grained forereef sands from the locality Rohožník - Konopiská are higher. This fact is not entirely clear but it can be probably connected with the process of algal photosynthesis.

c) The isotopic compositions of carbonate cements reflect their formation during interactions of carbonates with pore waters (successive isotopic exchanges between carbonate and water).

d) The $\delta^{13}C$ values of total organic matter from the Rohožník area are lower than values published for Miocene. This fact can be probably explained by the lower $\delta^{13}C$ values of dissolved bicarbonate in the sea-water in the Rohožník area.

e) Extremely low $\delta^{13}C$ and higher $\delta^{18}O$ values of carbonate concretions from calcareous clays (Rohožník - Konopiská) are probably the result of near-surface oxidation of methane. Such reactions are confined to the vicinity of fractured hydrocarbon reservoirs and thus could be a valuable guide to petroleum exploration.

f) The $\delta^{34}S$ value of gypsum concretion from the calcareous clays (Rohožník - Konopiská) shows that the sulphate representing the source of sulphur for this concretion was formed during the oxidation of sulphides. The positive $\delta^{18}O$ value found for gypsum concretion reflects its origin from water rich in isotope ^{18}O (formation waters or strongly evaporated meteoric waters).

5. References

Anati, D.A. & Gat J.R., 1989: Restricted marine basins and marginal sea environments. In: Fritz P., Fontes J.Ch. (Eds.), Handbook of Environmental Isotope Geochemistry, Vol. 3: The Marine Environment. Elsevier, Amsterdam, pp. 29-74.

Baráth I., 1992: Upper Badenian reef complex on the eastern margin of the Vienna Basin. Knihovnička ZPN (Hodonín), 15, 177-197.

Benejová, I. 1985: Faciálna analýza bádenských litotamniových vápencov na lokalite Rohožník. Manuskript, archív PriF UK Bratislava.

Brand U., 1981: Mineralogy and chemistry of the Lower Pensylvanian Kedrick fauna, Eastern Kentucky. Chem. Geol. (Amsterdam), 32, 17-28.

Buzek F., Michalíček M., Franců J. & Procházková V., 1992: Contribution to origin of gases from S-E flanks of the Bohemian Massif and West Carpathians. Research Report, Manuscript, Czech Geological Survey Praha. (In Czech.)

Buzek F. & Michalíček M., 1997: Origin of formation waters of S-E parts of the Bohemian Massif and the Vienna Basin. Applied Geochemistry (Amsterdam), 12, 333-343.

Claypool G.E., Holser W.E., Kaplan I.R., Sakai H. & Zak I., 1980: The age curves of sulphur and oxygen isotopes in marine sulphate and their mutual interpretation. Chem. Geol. (Amsterdam), 28, 199-260.

Čierna E., 1973: Mikropaläontologische und biostratigraphische Untersuchung einiger Bohrproben aus der weiteren Umgebung von Rohožník. Acta Univ. Comen. (Bratislava), 26, 113-187.

Hladíková J. & Buzek F., 1992: Vývoj univerzální separační aparatury pro stanovení $\delta^{13}C$. Manuscript, ČGÚ Praha. (In Czech.)

Hladíková J., Hladil J. & Zusková J., 1997: Discrimination between facies and global controls in isotope composition of carbonates: carbon and oxygen isotopes at the Devonian reef margin in Moravia (HV-105 Křtiny borehole). J. Czech Geol. Soc. (Praha), 42, 1-16.

Hladilová Š., 1991: Results of preliminary studies of the molluscan fauna from the Rohožník locality. Scripta (Brno), Geology, 21, 91-97.

Hoefs J., 1997: Stable Isotope Geochemistry. 4th Edition, Springer Verlag. New York.

Holec P., 1973: Fisch-Otolithen aus dem oberen Baden (Miozän) des nordöstlichen Teiles des Wiener Beckens (Gebiet von Rohožník). Geol. Zbor. Geol. carpath. (Bratislava), 24, 2, 393-414.

Holec P., 1975: Fisch-Otolithen aus dem Baden (Miozän) des nördlichen Teiles des Wiener Beckens und der Donau-Tiefebene. Geol. Zbor. Geol. carpath. (Bratislava), 26, 2, 253-266.

Holec P., 1978: Fischotolithen aus dem Baden (Miozän) des nördlichen Teiles des Wiener Beckens und des Donaubeckens in der Slowakei. Acta geol. et Geograph. Univ. Comen., Geol. (Bratislava), 33, 149-176.

Horák P., 1985: Miocénne otolity sedimentov íloviska cementárne v Rohožníku a hliniska tehelne v Devínskej Novej Vsi. Manuscript, PF UK Bratislava. (In Slovak.)

Hudson J.D., 1977: Stable isotopes and limestone lithification. J. Geol. Soc. London (London), 133, 637-660.

Kováč M., Baráth I., Marko F., Šutovská K., Uher P., Hladilová Š., Fordinál K. & Tuba L., 1991: Neogene sequences. In: Kováč M., Michalík J., Plašienka D., Putiš M., eds.: Malé Karpaty Mts. Geology of the Alpine-Carpathian junction. Guide to excursions, Konf., Symp., Sem., GÚDŠ Bratislava, 61-74.

Křibek B., 1997: Uhlíkaté formace Českého masívu a jejich mineralizace. Knihovna ČGÚ, 66. Český geologický ústav, Praha. (In Czech.)

Kučerová K., 1982: Ostrakódy bádenských sedimentov íloviska cementárne v Rohožníku. MS PF UK. Bratislava. (In Slovak.)

Kučerová K., 1984: Miocénne ostrakódy sedimentov íloviska cementárne v Rohožníku. MS PF UK. Bratislava. (In Slovak.)

Kučerová K., 1986: Bádenské a sarmatské ostrakódy íloviska v Rohožníku. Region. Geol. Západ. Karpát (Bratislava), 21, 113-115. (In Slovak.)

Lewan M.D., 1986: Stable carbon isotopes of amorphous kerogens from Phanerozoic sedimentary rocks. Geochim. Cosmochim. Acta. (Oxford), 50, 1583-1591.

Lloyd R.M., 1971: Some observations on recent sediment alteration ('micritization') and the possible role of algae in submarine cementation. In Bricker O.P. (ed.) Carbonate cements. Johns Hopkins Press, Baltimore, 72-79.

Marko F., Kováč M., Fodor L. & Šutovská K., 1990: Deformácia a kinematika miocénnej strižnej zóny severnej časti Malých Karpát (Bukovská brázda, hrabnícke súvrstvie). Mineralia Slov. (Spišská Nová Ves), 22, 399-410.

McCrea J.M., 1950: The isotopic composition of carbonate and paleotemperature scale. J.Chem. Physics (Lancaster), 18, 849 - 857.

Milliman J.D., 1974: Marine Carbonates. New York. Springer Verlag.

Mišík M., 1976: Geologické exkurzie po Slovensku. Bratislava. Slov. Ped. Nakl., 107. (In Slovak.)

Pachón Duarte J., 1989: Paleoekologické vyhodnotenie detailnej kvantitatívnej analýzy tanatocenóz foraminifer (báden viedenskej panvy). Manuscript PF UK Bratislava. (In Slovak.)

Pek I., Mikuláš R. & Lysáková G., 1997: Boring ichnofossils on mollusc shells from the Late Badenian at Rohožník (Malé Karpaty Mts., Slovakia). Zem. Plyn Nafta (Hodonín), 42, 1, 47-55.

Popp B., Takigiku R., Hayes J. M., Louds J. V. & Baker E.W., 1989: The post Paleozoic chronology and mechanism of 13C depletion in primary organic matter. Am. J. Sci. (New Haven), 289, 436-454..

Savin S.M., 1977: The history of the Earth's surface temperature during the past 100 million years. - Ann. Rev. Earth. Planet. Sci. (Amsterdam), 5, 319-355.

Schaleková A., 1973: Oberbadenische Corallinaceen aus dem Steinbruch Rohožník - Vajar an dem Westhang der Kleinen Karpaten. Acta Univ. Comen. (Bratislava), 26, 211-221.

Schaleková A., 1978: Riasové (litotamniové) vápence v bádene viedenskej, podunajskej a juhoslovenskej panvy Západných Karpát. Manuscript, PF UK Bratislava. (In Slovak.)

Šmejkal V. & Dubánek V., 1990: Izotopické rozlišení zdrojů sulfátové kontaminace podzemních a povrchových vod v blízkosti odkaliště energetického popílku. Vodní hospodářství (Praha), 3, 114-118. (In Czech.)

Šmejkal V. & Hladíková J., 1987: Metodiky stanovení izotopického složení uhlíku v geologických materiálech a kyslíku a síry v sulfátech. Manuscript, ČGÚ Praha. (In Czech.)

Yanagisawa F. & Sakai H., 1983: Thermal decomposition of barium sulphate for stable isotope analysis. Anal. Chem. (London), 985.

Cycles of different scale in the turbidites of the Magura nappe on the northern Orava, Western Carpathians (Campanian - Upper Eocene)

DANIEL PIVKO

Department of Geology and Paleontology, Faculty of Sciences, Comenius University, Mlynská dolina, 84215 Bratislava

Abstract. The schematic lithostratigraphic sections of the Rača and the Bystrica Units of the Flysch belt are quite well correlated with 2nd and 3rd order sea-level fluctuations. Disagreement in some part of sections is explained by tectonic movements, especially by the Laramian tectonic movements. In the Szczawina beds of the Rača Subunit (Maastrichtian) the cycles controlled by the 4th order sea-level fluctuations were observed. The cycles in thin-bedded turbidites probably correspond by its duration with 5th and 6th order fluctuation (Milankovitch cycles).

Key words: turbidites, cycles, sea-level fluctuations, Milankovitch, Cretaceous-Paleogene

Introduction

Studied area on the northern Orava is a part of the Magura Nappe of the Flysch belt of the Western Carpathians. The Flysch belt is the neo-alpine accrecionary wedge. It is created of some nappes. Each of them is built from several tectonic slices. They are mainly composed of deep-sea turbidite sequences deposited in a remnant oceanic basin (Einsele, 1992). In the studied area there were determined lithostratigraphic formations and members of the Rača and the Bystrica Subunits. In the sections and some outcrops there were identified the cycles of bed thickness and grain size changes of different scale. It is possible to correlate the cycles with sea level fluctuations of the second, third, forth, fifth and sixth orders?

Lithostratigraphic units

The studied area in Pilsko mountain region is situated in the frontier between Slovakia and Poland. It was possible to arrange only schematic lithostratigraphic sections both of the Rača and both of the Bystrica Subunits in spite of covering of the area. Age of the formations was based on determination of nannofossils, agglutinated forams and correlation with similar formations in Poland part of the Magura Nappe. Names of the intervals of turbidite beds are based on Bouma (1962) and Lowe (1982).

Rača Subunit is composed of the following formations and members:

Haluszowa Formation - (Campanian - Lower Maastrichtian) is built by hemipelagic variegated mudstones with less portion of medium-bedded turbidite beds (see Malata & Oszczypko, 1990, Malata et al. 1996). The ideal bed is composed from sandstone and siltstone $T_{(ab)cd}$ and variegated marlstone T_e (Pivko, 1991, Pivko, 1994). The formation can be compared with Variegated shales (Sikora & Żytko, 1959), Cebula variegated marls (Golonka & Wójcik, 1978) and upper part (Campanian - Maastrichtian) of Kaumberg Formation (Švábenická et al., 1997).

The formation contained nannofossils: *Aspidolithus parcus* (STRADNER) NOËL, *Aspidolithus parcus contrictus* (HATTNER) PERCH-NIELSEN, *Arkhangelskiella cymbiformis* VEKSHINA, *Quadrum gothicum* (DEFLANDRE) PRINS & PERCH-NIELSEN, *Quadrum sissinghii* PERCH-NIELSEN, *Calculites obscurus* (DEFLANDRE) PRINS & SISSINGH, *Lucianorhabdus maleformis* REINHARDT, *Eifelithus eximius* (STOVER) PERCH-NIELSEN (POTFAJ in PIVKO et al., 1991).

Szczawina Member (Maastrichtian) is composed of massive sandstones (pebbly sandstones) S_3 or thick beds with the domination of sandstones T_{a-e}. It is interrupted by layers with variegated mudstones and thin-bedded turbidites T_{cde} (Pivko, 1994). The member is approximately comparable with Szczawina Sandstones (Sikora & Żytko, 1959, Cieszkowski et al., 1989, Ryłko et al. 1992, Malata et al. 1996) and lower part of Altlengbach Formation (Schnabel, 1992, Faupl, 1996).

The member belongs to zone *Caudammina gigantea* (GEROCH) with next species: *Caudammina ovulum* (GRZYBOWSKI), *Rhabdammina cylindrica* GLAESSNER, *Rhabdammina* ex gr. *discreta* (BRADY), *Dendrophrya excelsa* (GRZYBOWSKI), *Dendrophrya latissima* GRZYBOWSKI, *Saccammina placenta* (GRZYBOWSKI) (Pivko & Bubík, prepared paper, Korábová in Pivko et al. 1991).

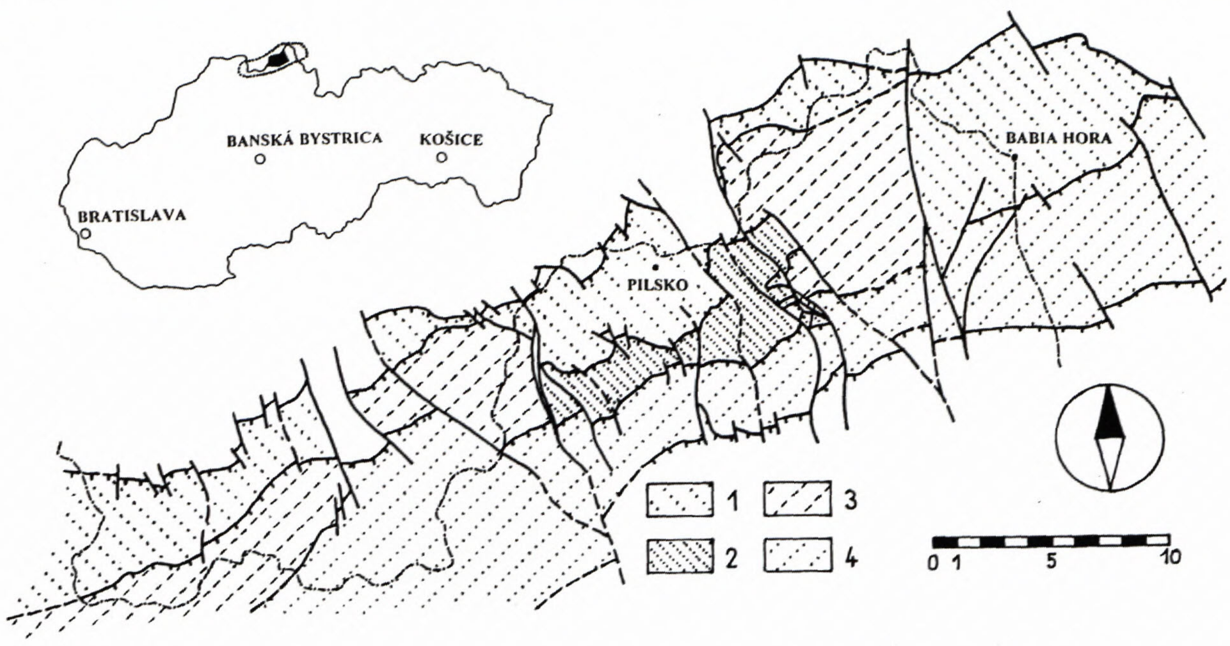


Fig.1 Position and tectonic map of the studied area and its surrounding. Names of the slices on the boundary of the Rača and Bystryca Subunits: 1 - „Outer Rača Unit„, 2 - „Inner Rača Unit„, 3 - „Outer Bystrica Unit„ and 4 - „Inner Bystrica Unit„.

Ropianka Member (Uppermost Maastrichtian - Upper Paleocene) is created with thin- to medium-bedded turbidites $T_{(ab)cde}$ and grey hemipelagic mudstones (see Ślączka & Miziołek, 1995). The beds are similar to Inoceramian Beds (Sikora & Żytko, 1959, Książkiewicz, 1966), Ropianka Beds (Golonka & Wójcik, 1978, Ryłko et al. 1992), Ropianka Formation (Oszczypko, 1992b), Shaly-sandstone member of Soláň Formation (Pesl, 1968) or Ráztoka Member of Soláň Formation (Švábenická et al., 1997). The closed is the upper part of the Altlengbach Formation (Schnabel, 1992, Faupl, 1996).

Age was based on litological comparison with neighborough area (Sikora & Żytko, 1959) and the position of the member.

Łabowa Shale Formation (Upper Paleocene - Lower Eocene) contains variegated hemipelagic mudstones and thin-bedded turbidites T_{cde} and T_{de} (see Oszczypko, 1991, Oszczypko, 1992b). Conglomeratic beds are very rare (Ciężkowice Sandstone type). It is possible to correlate the formations with Lower Variegated Shales and Ciężkowice Sandstones (Sikora & Żytko,1959) and Variegated shales or beds (Książkiewicz, 1966, Pesl, 1968, Golonka & Wójcik, 1978, Ryłko et al. 1992).

In the formation there are *Rhabdammina* ex gr. *discreta* (BRADY), *Dendrophrya excelsa* (GRZYBOWSKI), *Dendrophrya latissima* GRZYBOWSKI, *Sacammina placenta* (GRZYBOWSKI), *Glomospira charoides* (JONES et PARKER), *Glomospira gordialis* (JONES et PARKER), *Caudammina ovulum* (GRZYBOWSKI), *Trochammminoides irregularis* WHITE, *Globigerina* ex gr. *eocaena* GÜMBEL (Korábová in Pivko et al., 1991).

Veselé Formation. (Upper Maastrichtian - Lower Eocene) is composed by variegated and grey hemipelagic mudstones and thin-bedded turbidites T_{cde} and T_{de}. In the middle part there are medium- to thick-bedded turbidites T_{a-e} (Pivko & Bubík, prepared paper). The formation has some common features of the Ropianka Member and the Labowa Shale Formation.

Agglutinated forams in the formation are *Rhabdammina* ex gr. *discreta* (BRADY), *Dendrophrya* cf. *robusta* GRZYBOWSKI, *Saccammina placenta* (GRZYBOWSKI), *Glomospira charoides* (JONES et PARKER), *Glomospirella gorayskii* (GRZYBOWSKI), *Ammodiscus cretaceous* (REUSS), *Caudammina ovulum* (GRZYBOWSKI), *Hormosina ovuloides, Trochamminoides irregularis* WHITE, *Trochamminoides subcoronatus* (GRZYBOWSKI) (Korábová in Pivko et al., 1991).

Beloveža Formation (Uppermost Lower Eocene - Middle Eocene) is built by Hieroglyphic Member. In upper part of the formation there is the Osielec sandstone Member. *The Hieroglyphic Member* (Uppermost Lower Eocene - Middle Eocene) is created by thin-bedded turbidites T_{cde} with less portion of thick-bedded ones T_{abcde} (see Oszczypko, 1992b). *The Osielec Sandstone Member* (Middle Eocene) is composed of thick-bedded turbidites with prevailing of sandstones with glauconite over calcareous mudstones T_{a-e} (see Książkiewicz, 1966). The Hieroglyphic Member is comparable with Beloveža Member without red mudstones (Pesl, 1968). The Osielec Sandstone Member has some litological similarity to Vsetín Member (Pesl, 1968) and Steinberg „flysch„ (see Faupl, 1996) and some litological similarity but not age equivalent to Greifenstein Formation, Gablitz Member and Glauconite Formation (see Faupl, 1996). The sandstones of the member were also included to Pasierbiec Sandstones (Sikora & Żytko, 1959, Książkiewicz, 1966).

The next nannofossils were identified in the formation: *Chiasmolithus grandis* (BRAMLETTE et SULLIVAN) RADOMSKI, *Cyclicargolithus* cf. *floridanus* (ROTH et HAY) BUKRY, *Dictyococcites bisectus* (HAY, MOHLER et

WADE) BUKRY et PERCIVAL, *Dictyococcites* cf. *scrippsae* BUKRY et PERCIVAL, *Discoaster barbadiensis* TAN SIN HOK, *Discoaster binodosus* MARTINI, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Ericsonia formosa* (KAMPTNER) HAQ, *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER, *Sphenolithus radians* DEFLANDRE (Potfaj in Pivko et al. 1991).

Zlín Formation - Kyčera Member (Upper Eocene) is very thick. Lower part of the Member is thick-bedded turbidites T_{a-e} to massive sandstones S_3, middle part massive sandstones and upper part massive to thick-bedded turbidites. The member corresponds to Magura Sandstone (Sikora & Żytko, 1959, Książkiewicz, 1966, Golonka & Wójcik, 1978), Magura Formation (see Oszczypko, 1992b) and bigger part of Babia hora Sandstone (Matějka & Roth, 1952).

Potfaj (in Pivko, 1991) determined the nannofossils: *Chiasmolithus grandis* (BRAMLETTE et SULLIVAN) RADOMSKI, *Chiasmolithus eograndis* PERCH-NIELSEN, *Chiasmolithus* cf. *modestus* PERCH-NIELSEN, *Chiasmolithus solitus* (PERCH-NIELSEN) LOCKER, *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY, *Discoaster barbadiensis* TAN SIN HOK, *Discoaster binodosus* MARTINI, *Discoaster deflandrei* BRAMLETTE et RIEDEL, *Discoaster distinctus* MARTINI, *Discoaster diastypus* BRAMLETTE et SULLIVAN, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Discoaster nonaradiatus* KLUMP, *Discoaster saipanensis* BRAMLETTE et RIEDEL, *Discoaster sublodoensis* BRAMLETTE et SULLIVAN, *Discoaster tanii* BRAMLETTE et RIEDEL, *Ericsonia formosa* (KAMPTNER) HAQ, *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER, *Sphenolithus radians* DEFLANDRE.

Bystrica Subunit is built of the formations and the members:

Ropianka Member (Paleocene) is composed of thin-bedded turbidites T_{cde} and T_{de} with variegated mudstones (see Ślączka & Miziołek, 1995). The member is similar to Inoceramian Beds (Książkiewicz, 1966), Ropianka Beds (Golonka & Wójcik, 1978, Ryłko, 1992 - „comlex b„, Malata et al., 1996), Ropianka Formation (Oszczypko, 1992b) and Shaly-sandstone member of Soláň Formation (Pesl, 1968).

Age was based on litological comparison with neighborough area (RYŁKO, 1992) and forams: *Rhabdammina* ex gr. *discreta* (BRADY), *Dendrophrya latissima* GRZYBOWSKI, *Sacammina placenta* (GRZYBOWSKI), *Glomospira serpens* (GRZYBOWSKI), *Trochammminoides irregularis* WHITE, *Trochammminoides proteus* (KARRER), *Globigerina* sp. (KORÁBOVÁ in PIVKO et al., 1991).

Szczawina Sandstone Member (Upper Paleocene) is the sequence of massive sandstones S_3 very similar to the Szczawina Sandstone in Rača Subunit, but other age. The member is litologically closed to Szczawina Sandstone (Cieszkowski et al., 1989, Oszczypko 1992b, Malata et al. 1996), „muscovite sandstones„ in Inoceramian Beds (Książkiewicz, 1966) and also by age closed to „comlex „c„ of Ropianka Beds (Ryłko, 1992).

Age was determined after the superposition of the member in the Inoceramian Member.

Beloveža Formation (Lower Eocene) is divided to the Lower and the Upper Beloveža Member. *The Lower Beloveža Member* (Lower Lower Eocene) is built by thin-bedded turbidites T_{cde} and variegated mudstones and *Upper Beloveža Member* (Upper Lower Eocene) of thin-bedded turbidites T_{cde}. The Lower Beloveža Member can be compared with Variegated shales (Golonka & Wójcik, 1978), „Beloveža Member with variegated shales„ (Ryłko, 1992) or Łabowa Shale Formation (Malata et al., 1996, partly Oszczypko, 1991). The Upper Beloveža Member is comparable with thin-bedded part of the Beloveža Formation (Golonka & Wójcik, 1978, Oszczypko, 1991, Ryłko, 1992, Malata et al., 1996).

The nannofossils of the formation are: *Discoaster barbadiensis* TAN SIN HOK, *Discoaster deflandrei* BRAMLETTE et RIEDEL, *Discoaster distinctus* MARTINI, *Discoaster gemmifer* STRADNER, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Chiasmolithus expansus* (BRAMLETTE et SULLIVAN) GARTNER, *Sphenolithus moriformis* (BRÖ NNIMANN et STRADNER) BRAMLETTE et WILCOXON, *Sphenolithus radians* DEFLANDRE, *Tribrachiatus orthostylus* SHAMRAI (Korábová in Pivko et al., 1991).

Vychylovka Formation (Uppermost Lower Eocene - Middle Eocene) consists of thin-bedded T_{cde} and medium- to thick-bedded turbidites $T_{(a)b-e}$ with prevailing of marlstones - closed to Łącko type (see Potfaj, 1989). The formation has similarity with upper part of Beloveža Formation and lower part of Łącko Beds or Marls (Sikora & Żytko, 1959, Książkiewicz, 1966, Golonka & Wójcik, 1978, Ryłko, 1992), with some parts of Beloveža, Żeleznikowa and Bystrica Formation (Oszczypko, 1991, Malata et al., 1996). Some features are similar to „transitional beds„ (Książkiewicz, 1966).

The formation belongs to nannofossils zones NP13-NP17: *Chiasmolithus expansus* (BRAMLETTE et SULLIVAN) GARTNER, *Chiasmolithus grandis* (BRAMLETTE et SULLIVAN) RADOMSKI, *Cribrocentrum coenurum* (REINHARDT) PERCH-NIELSEN, *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY, *Dictyococcites bisectus* (HAY, MOHLER et WADE) BUKRY et PERCIVAL, *Discoaster barbadiensis* TAN SIN HOK, *Discoaster binodosus* MARTINI, *Discoaster deflandrei* BRAMLETTE et RIEDEL, *Discoaster distinctus* MARTINI, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Discoaster saipanensis* BRAMLETTE et RIEDEL, *Ericsonia formosa* (KAMPTNER) HAQ, *Nannotetrina cristata* (MARTINI) PERCH-NIELSEN, *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER, *Reticulofenestra umbilica* (LEVIN) MARTINI et RITZKOWSKI, *Sphenolithus editus* PERCH-NIELSEN, *Sphenolithus moriformis* (BRÖNNIMANN et STRADNER), *Sphenolithus radians* DEFLANDRE (Korábová & Potfaj in Pivko et al., 1991).

Zlín Formation (Middle - Upper Eocene) is composed of Bystrica and Kýčera Member (see Pesl, 1968). In *the Bystrica Member* (Middle Eocene) there are marlstones (Łącko type), which prevails over sandstones in thick-bedded turbidites $T_{(a)b-e}$ and in *the Kýčera Member* (Middle - Upper Eocene) there are thick-bedded sandy turbidites T_{a-e} to massive sandstones S_3. The Bystrica

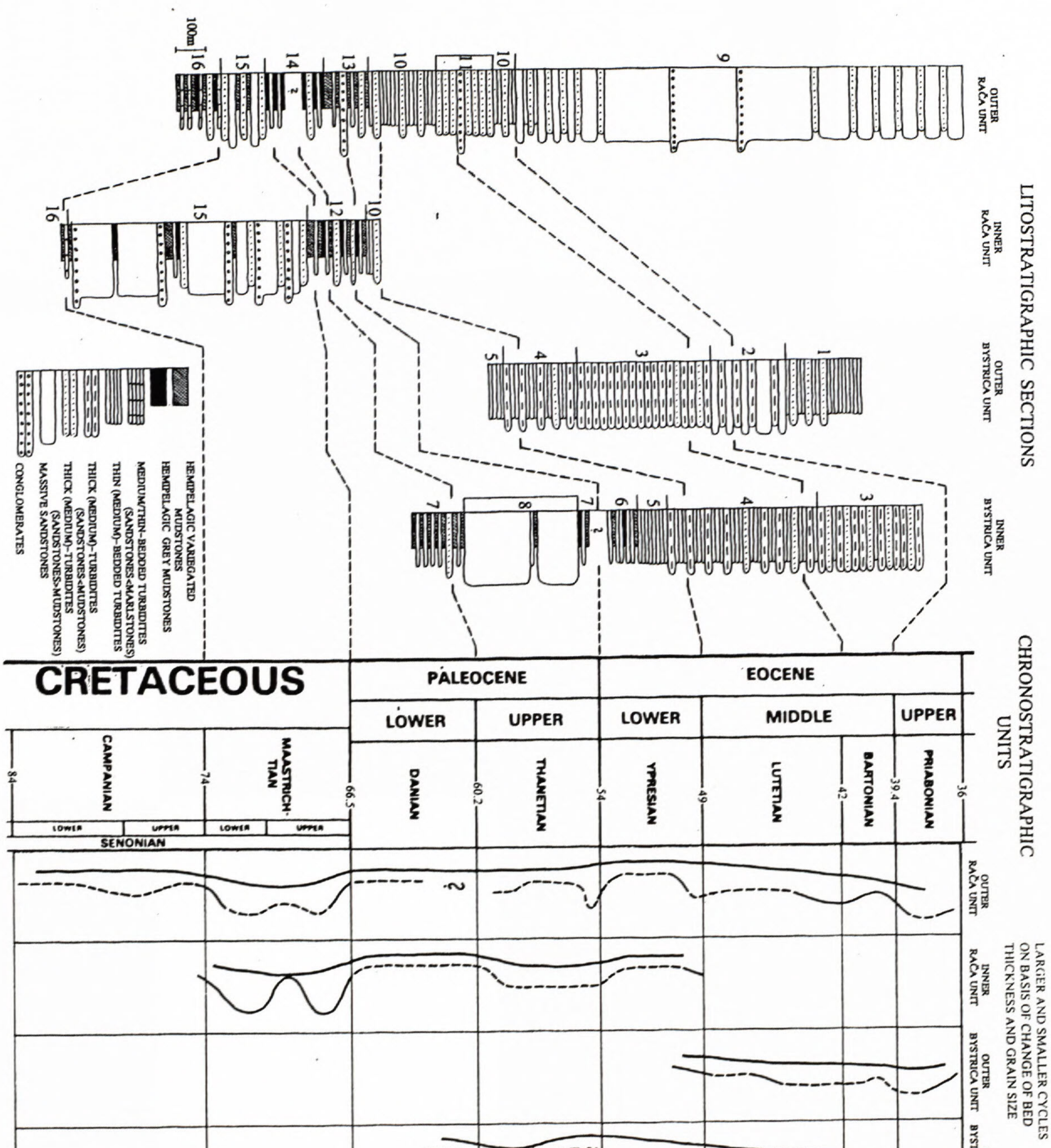


Fig. 2 Comparison of the schematic lithostratigraphic sections of the Rača and the and the Bystrica Subunits and their cycles of bed thickness and grain size with 2[nd] *and 3*[rd] *order sea level fluctuations (Haq et al., 1987).* Numbers in the sections: 1-8 - Bystrica Subunit: 1 - Malcov Formation, 2 - Zlín Formation - Kýčera Member, 3 - Zlín Formation- Bystrica Member, 4 - Vychylovka Formation, 5 - Beloveža Formation - Upper Beloveža Member, 6 - Beloveža Formation - Lower Beloveža Member, 7 - Ropianka Member, 8 - Szczawina Sandstone Member, 9-16 - Rača Subunit: 9 - Zlín Formation - Kyčera Member, 10 - Beloveža Formation - Hieroglyphic Member, 11 -Beloveža Formation - Osielec Sandstone Member, 12 - Veselé Formation, 13 - Labawa Shale Formation, 14 - Ropianka Member, 15 - Szczawina Member and 16 - Haluszowa Formation

Member is similar to Łącko Beds (Sikora & Żytko, 1959, Książkiewicz, 1966, Ryłko, 1992) and Bystrica Formation (Oszczypko, 1991). The Kýčera Member can be correlated with Magura Sandstone or Beds (Sikora & Żytko, 1959, Książkiewicz, 1966, Golonka & Wójcik, 1978) and Magura Formation (Oszczypko, 1991).

In the Bystrica Member there are *Cribrocentrum coenurum* (REINHARDT) PERCH-NIELSEN, *Cyclicargolithus floridanus* (ROTH et HAY) Bukry, *Chiasmolithus* cf. *expansus* (BRAML. et SUL.) GARTNER, *Chiasmolithus* cf. *modestus* PERCH-NIELSEN, *Discoaster barbadiensis* TAN SIN HOK, *Discoaster binodosus* MARTINI, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER, *Reticulofenestra umbilica* (LEVIN) MARTINI et RITZKOWSKI, *Sphenolithus moriformis* (BRÖNNIMANN et STRADNER) (Korábová & Potfaj in Pivko et al. 1991).

In the Kýčera Member there are *Chiasmolithus grandis* (BRAMLETTE et SULLIVAN) RADOMSKI, *Chiasmolithus eograndis* PERCH-NIELSEN, *Chiasmolithus modestus* PERCH-NIELSEN, *Chiasmolithus solitus* (PERCH-NIELSEN) LOCKER, *Cribrocentrum coenurum* (REINHARDT) PERCH-NIELSEN, *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY, *Dictyococcites bisectus* (HAY, MOHLER et WADE) BUKRY et PERCIVAL, *Dictyococcites callidus* PERCH-NIELSEN, *Dictyococcites scrippsae* BUKRY et PERCIVAL, *Discoaster* barbadiensis TAN SIN HOK, *Discoaster deflandrei* BRAMLETTE et RIEDEL, *Discoaster* cf. *distinctus* MARTINI, *Discoaster lodoensis* BRAMLETTE et RIEDEL, *Discoaster nonaradiatus* KLUMP, *Discoaster saipanensis* BRAMLETTE et RIEDEL, *Discoaster sublodoensis* BRAMLETTE et SULLIVAN, *Ericsonia formosa* (KAMPTNER) HAQ, *Helicosphaera* cf. compacta BRAMLETTE et WILCOXON, *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER, *Reticulofenestra umbilica* (LEVIN) MARTINI et RITZKOWSKI, *Sphenolithus radians* DEFLANDRE, *Sphenolithus spiniger* BUKRY (Korábová & Potfaj in Pivko et al. 1991).

Malcov Formation (Upper Eocene-?Oligocene) is composed of thin (medium)-bedded turbidites T_{cde}. The formation is very similar to the same one in the Krynica or possibly Rača Subunit (Birkenmajer & Oszczypko, 1989, Oszczypko et al., 1990, Potfaj et al., 1991, Oszczypko, 1992b).

The thickness of the lithostratigraphic units is visible in schematic sections on fig.2.

Cycles in deep-sea turbidites

In the formations of studied area there are the cycles on the basis of change of bed thickness, grain size and facies. The cycles are of a different scale. The cycles with thickening- and thinning-upward, coarsening- and fining-upward trends of turbidite beds are a common phenomenon in turbidite sequences. It is result of an interplay of sedimentary, topographic, tectonic and sea-level effects (Stow, 1986).

The cyclicity in sediments is of a global and a local origin. The local ones are control by mechanism in the sedimentary prism itself, for instance by switching of turbidite bodies and by a local tectonics. The sea-level fluctuations control changes in sediment, which are observed on all the Earth.

It was recognised sea level fluctuations of the first to sixth orders (Haq et al., 1987, Vail et al., 1991, Hoedemaeker & Leereveld, 1996). *1st order sea-level fluctuations* are major continental flooding cycles with duration over 50 million years. *2nd order fluctuations* are major transgressive - regressive cycles with time span of a few tens of millions years. *3rd order fluctuations* from half to a few million years produce sequences studied by sequence stratigraphy. Causes of 1st to 3rd order sea-level fluctuations are not quite understood. Probably there are some processes in earth mantle. *4th order fluctuations* are more expressive than 3rd order ones during icehouse (existence of polar caps). Their duration is from 80 to 500 thousand years. *5th order fluctuations* last from 30 to 80 thousand years and *6th order* one from 10 to 30 thousand years. During greenhouse (without polar caps) 4th to 6th order fluctuations are less expressive than 3rd order ones and they are most probably caused by climatic changes driven by orbital forcing. They are known like *Milankovitch cycles.*

4th order sea-level fluctuations are influenced by *Milankovitch cycle of eccentricity*, 5th order one by *cycle of obliquity* and 6th order one by *cycle of precession* (Hoedemaeker & Leereveld, 1996).

Turbidite sequences are restricted only to fall and low-stand of sea-level after models of sequence stratigraphy (Posamentier et al., 1988, Van Wagoner et al., 1988, Vail et al., 1991). It is very simplified. Turbidites are known also from transgressive and high-stand of sea-level (Shanmugam & Moiola, 1988, Mutti, 1992).

The thickness of deep-sea turbidites is controlled by global sea-level fluctuations. The fall of sea level means the increase of amount material transported to deep sea. This is the consequence of the approach of river deltas to deposition area in deep sea and of the erosion of emerged shallow sea sediments. On the contrary the rise of sea level causes the decrease of amount material, the enlargement of distance between the sources of clastic material and deep-sea. The tectonic uplift of source area and climate also control amount of material transported to deep-sea.

Rate and frequency of deposition

It was necessary to compute the frequency of deposition because of the knowledge of the duration of the cycles The input data are the thickness of lithostratigraphic units, the duration of lithostratigraphic units and average bed thickness of lithostratigraphic units. The thickness of lithostratigraphic units was estimated from the geologic profiles of the geologic map and the correlation with surrounding regions. The duration of lithostratigraphic units was based on biostratigraphy, correlation with surrounding areas and the third order fluctuations of sea-level (Haq et al. 1988, fig. 2). The average bed thickness was computed from data measured in outcrops.

From the thickness of a lithostratigraphic unit and the average bed thickness was computed the number of beds in a lithostratigraphic unit. From the duration of a lithostratigraphic unit and number of beds in a lithostratigraphic unit was gained the *frequency* of beds (number of years between deposition of two following turbidite beds).

Rate of deposition (thickness of sediment per thousand years) was computed from the thickness and the duration of a lithostratigraphic unit. All computed results are very approximated because of inaccurate input data. But they give good image of the rate and the frequency of deposition and are suit to the estimation of the duration of cycles.

The frequency of turbidite beds varies from about 1.5 to 30 thousand years per one bed. The rate of deposition change from 1.3 to 38 centimetres per thousand years (Tab.1).

Tab.1 Approximated frequencies and rates of deposition in some lithostratigraphic units

	thickness of a lithostrat. unit (m)	average thickness of bed (cm)	number of beds in a lithostrat. unit	duration of a lithostrat. unit (million years)	frequency of deposition (x thousands years / one turbidite bed)	rate of deposition (x cm / 1000 years)
Haluszowa Fm.	150	40	380	12	30	1.3
Szczawina Mb. (Rača S.)	800	?		4		
- thick-bedded parts	710	120	600	2	3.3	35
- middle thin-bedded part	60	? 15	? 300	2	? 5	3
Veselé Fm.	350	?		18		
- lower thin-bedded part	150	6	2 500	7	2.8	2
- upper thin-bedded part	125	7.5	1 700	? 3.5	? 2.5	? 3.5
Labowa Sh. Fm.	150	? 5	? 3 000	7	? 2.5	2
Hieroglyph Mb.	225	11	2 000	4.5	2.2	5
Upper Beloveža Mb.	? 100	6	? 1 700	2.5	? 1.5	? 4
Kýčera Mb. (Rača S.)	1 500	200	750	4	5.5	38

Cycles in the turbidites of the Magura unit

Cycles in the schematic sections

In the schematic sections of the Rača and the Bystrica Subunit there are the trends of changes of bed thickness and grain size of material (Fig. 2). We can distinguish larger and smaller trends. One cycle is the thickening/coarsening upward and following thinning/fining upward trend.

Larger cycles

On the curve of the trends (Fig. 2) we can see thickening/coarsening upward trend in the Lower Maastrichtian and the opposite one in the the Upper Maastrichtian. In the Upper Paleocene there is less the expressive thickening/coarsening upward and thinning/fining upward trend. From the Lower Eocene to the Upper Eocene there is the thickening/coarsening upward trend. The duration of the cycles is 13 and 20 million years.

Smaller cycles

Larger cycles are created by a few smaller ones (Fig. 2). Less expressive cycle is in the Haluszowa Formation of the Rača Subunit in the Campanian. Two more expressive cycles are in the Szczawina Member of the Rača Subunit during the Maastrichtian. One cycle is in the Veselé Formation of the Rača Subunit and the marked ones in the Ropianka Formation during the Upper Paleocene. On the border of the Paleocene and the Eocene there is one expressive cycle in the Labowa Shale Formation of the Rača Subunit and less visible one in the Beloveža Formation of the Bystrica Subunit. The marked cycle is in the Middle Eocene in the Beloveža Formation in the Rača Subunit and in the Vychylovka Formation and the Bystrica Member of the Bystrica Subunit. Very marked cycle is in the Kyčera beds in the Upper Eocene. The duration of the cycles is from 3 to 7 Ma.

Cycles in the Szczawina Member of the Rača Subunit

In the schematic section of the Inner Rača Subunit there were the sequences of the Szczawina Member worked out more detail. The sequences have thickness 300 and 410 metres. Both sequences probably correspond to falls of sea-level of 3rd order during the middle and upper Maastrichtian (Fig. 2) The sequences are divided to several parasequences (Fig. 3). The parasequences with the thick-bedded to massive sandstones are disturbed by the thin-bedded turbidites with variegated hemipelagic mudstones. The thickness of the parasequences is from about 50 to 200 metres. If both sequences lasted about 2 Ma, the parasequences approximately correspond to time

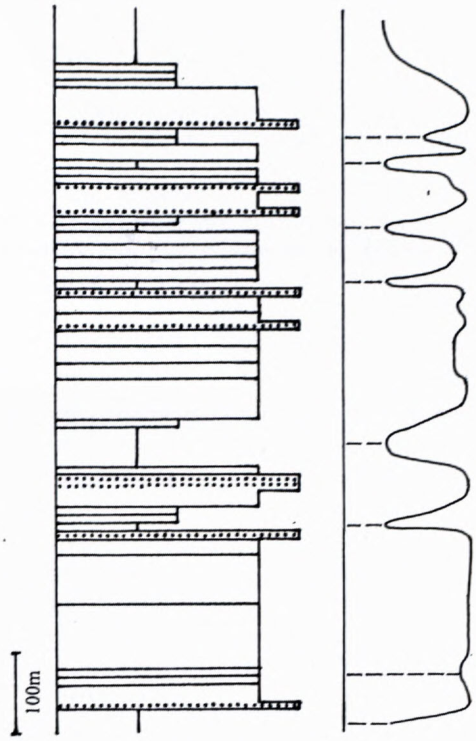


Fig. 3 - The cycles in the Szczawina Member of the Rača Subunit. In the first column there is the lithostratigraphic section of the member with conglomeratic beds, massive sandstones, medium-bedded and thin-bedded turbidites. The second column shows the cycles of bed thickness and grain size. The dotted lines marked the most probable borders of the cycles.

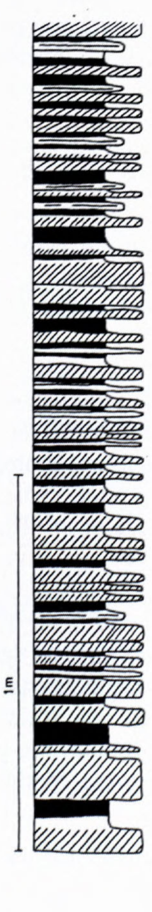


Fig.4 - Thin-bedded turbidites of the Upper Beloveža Member are created by cross-laminated sandstones (Tc), horizontally laminated siltstones (Td) and calcareous mudstones (Te). Between turbidite beds are hemipelagic non-calcareous mudstones (black colour).

span from 75 to 600 thousand years. Time span of the parasequences is not possible to compute from biostratigraphy. The biostratigraphy can resolve, in most cases, only the duration of 3rd-order cycles (Mutti 1992).

Cycles in the outcrops of thin-bedded turbidites

The cycles of smaller orders were searched in thin-bedded turbidites (Fig. 4) because of large amount beds in a outcrop and less influence of the processes in deep sea fan because this type of sediments were deposited on fringe of it. We observed cycles in the Upper Beloveža Member (Fig. 4) of the Bystrica Subunit, the Labowa Shale Formation and the Hieroglyphic Member of the Rača Subunit.

Firstly the rhythmograms of beds were arranged (Fig. 5-7). A rhythmogram is composed of thickness of sandstones (siltstones) and mudstones. On the rhythmograms there are possible to observe the various cycles of change of thickness. The changes of the bed thickness are not continuous. Bed by bed thickening (thinning)-upward cycles was not as often as oscillating (zigzag) ones. The arrangement of three beds with the oscillating changes of the thickness has approximately twice frequency than continuous thickening (thinning) of three beds. It corresponds to the theoretically computed random arrangement.

Because of better readability of a rhythmogram it was necessary to reduce influence of random arrangement. The curve of the three point moving average (average from tree values - thickness of bed and thickness of closed ones) was computed both for sandstones and for whole beds, on which the cycles of about 4 to 9 beds are visible (Fig. 5-7). The peaks of the cycles computed from sandstones and whole beds are not quite in accord. It is caused by less reliable data from whole beds because hemipelagic mudstones are included here. The duration of the cycles is after the frequency of deposition (Tab. 1) about 7 to 20 thousand years.

Because of better readability of the larger cycles the curve of the nine point moving average was arranged only for sandstones because of better reliability (Fig. 5-7). On the curve there are visible the cycles of about 11 to 30 beds. The duration of the cycles is about 28 to 75 thousand years. The extreme values were excluded when the cycles was computed.

Discussion - possible causes of the cycles

The cycles in schematic sections and outcrops were correlated with sea-level fluctuations. The rise on the sea-level curve was approximately expressed by thinning-upward and fining-upward turbidite beds. On the contrary the sea-level fall meant thickening-upward and coarsening -upward ones. The differences off this law are discussed.

The large cycles in the schematic sections approximately correspond to *2nd order sea-level fluctuations* (Fig. 2). Agreement is interrupted on some parts of the sections probably because of tectonic movements. For

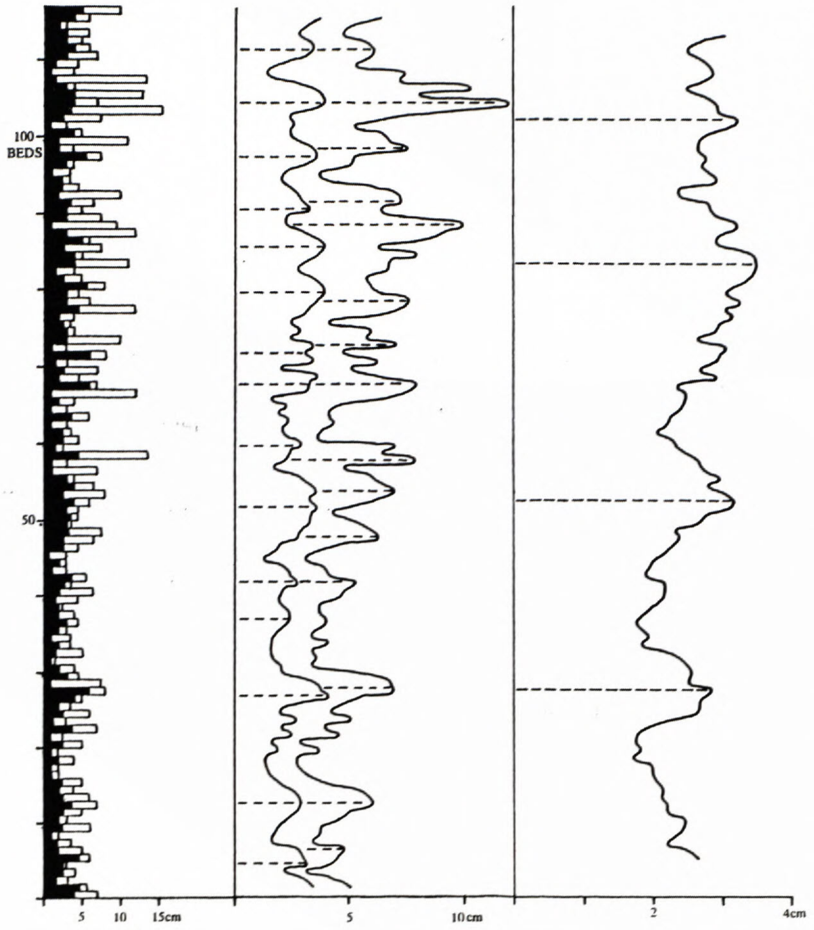


Fig. 5 Upper Beloveža Member of the Bystrica Subunit. On the first column there is rhythmogram with bed thickness of sandstones (black) and mudstones (white). The second column shows the curves of the three point moving average one for sandstones and the other for whole beds. The peaks of cycles are marked with dotted lines. The third column pictures the curve of the nine point moving average from sandstone parts of beds. Similarly dotted lines indicate the peaks of cycles.

instance during the Campanian when sea-level rose the thickness of turbidite beds were approximately uniform. The tectonic control of the sequences was expressive on the border of the Maastrichtian and the Paleocene. At that time there was marked thinning/fining-upward beds while sea-level fell slowly. Probably in the Paleocene (from the uppermost Maastrichtian) subsidence prevailed over sea-level fall, maybe expression of the Laramian tectonic movements (Roth, 1980).

Pyrite, glauconite, phosphorite nodules, authigenic dolomite and organic rich sediment are typical for relative rise of sea-level - transgressive systems of 3rd order sea-level fluctuation (Hoedemaeker & Leereveld, 1996). In some part of the lithostratigraphic section there was found increased amount of *glauconite*, but it is not possible to link his appearance with transgressive sequences of 3rd order sea-level fluctuation. Probably the occurrence of glauconite has connection with 2nd order fluctuation. Glauconite is the most abundant in the Middle Eocene, when sea-level of 2nd order fluctuation fell. In the time probably the shallow sea sediment were eroded and redeposited to deep-sea. The shallow sea sediment with large amount of glauconite were deposited during the rise of 2nd order fluctuation on border of the Paleocene and the Eocene.

The smaller cycles in the lithostratigraphic sections are well correlated with *3rd order sea-level fluctuations* (Fig. 2). Because of insufficient biostratigraphy some parts of the lithostratigraphic sections agree with 3rd order sea-level curve only approximately. Some of the cycles are longer than fluctuations on the curve of 3rd order. Some of the cycles really correspond to two or more 3rd order fluctuations. It is caused by the insufficient preciseness of some parts of the lithostratigraphic sections because of small outcropping.

The large rate of deposition in the Maastrichtian and the Upper Eocene, when the material was derived from south source, probable has not only connection with the fall of sea level (Oszczypko, 1992a) but also has connection with the tectonic movements (uplift) during the Laramian (Maastrichtian) tectonic phase in the area of Klippen belt and the Ilyrian (Upper Eocene) tectonic phase in the inner parts of Magura basin.

The cycles in schematic lithostratigraphic sections confirm the opinion that the large scale cyclicity results from sea level fluctuation (Shanmugam & Moiola, 1988) or variation in tectonic activity in the source area (Klein, 1985).

The cycles in the schematic sections seem to be deposited continuously without respect to high- or low-stand of sea-level. Sequence stratigraphy restricts the timing of deep-water siliciclastic systems to periods of relative low-stand of sea level (Posamentier et al., 1988, Van Wagoner et al., 1988 Vail et al., 1991). Mutti (1992) considers it as a lack of the model.

The parasequences in the Szczawina Member of the Rača Subunit with time span from 75 to 600 thousand years the most probably correspond with *4th order sea-level fluctuations* (Tab. 2). The fluctuations are controlled by climatic changes developed by orbital cycles of eccentricity (Milankovitch cycle). Because of insufficient outcropping and tectonic complications it was not possible to find all the cycles.

Turbidites seem to be not suitable to search the cycles of smaller scales. They are event deposits and not reflect continuous change of sea-level or other conditions. But from results the evident cyclicity at least two scales are visible in thin-bedded turbidites. The turbidites are point records of that time conditions. Similarly the continuous changes of sea-level or climate are searched from point samples from carbonates.

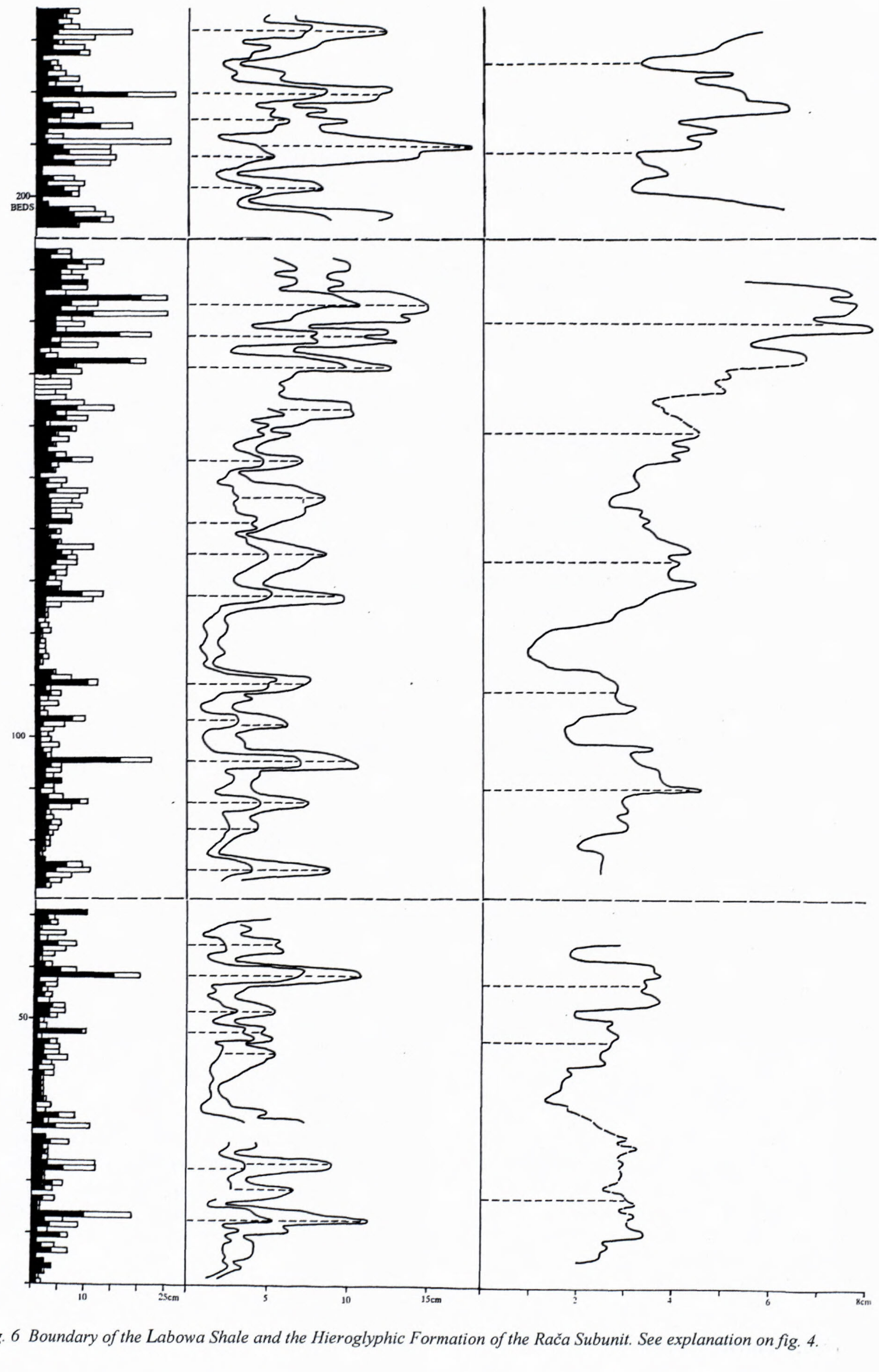


Fig. 6 Boundary of the Labowa Shale and the Hieroglyphic Formation of the Rača Subunit. See explanation on fig. 4.

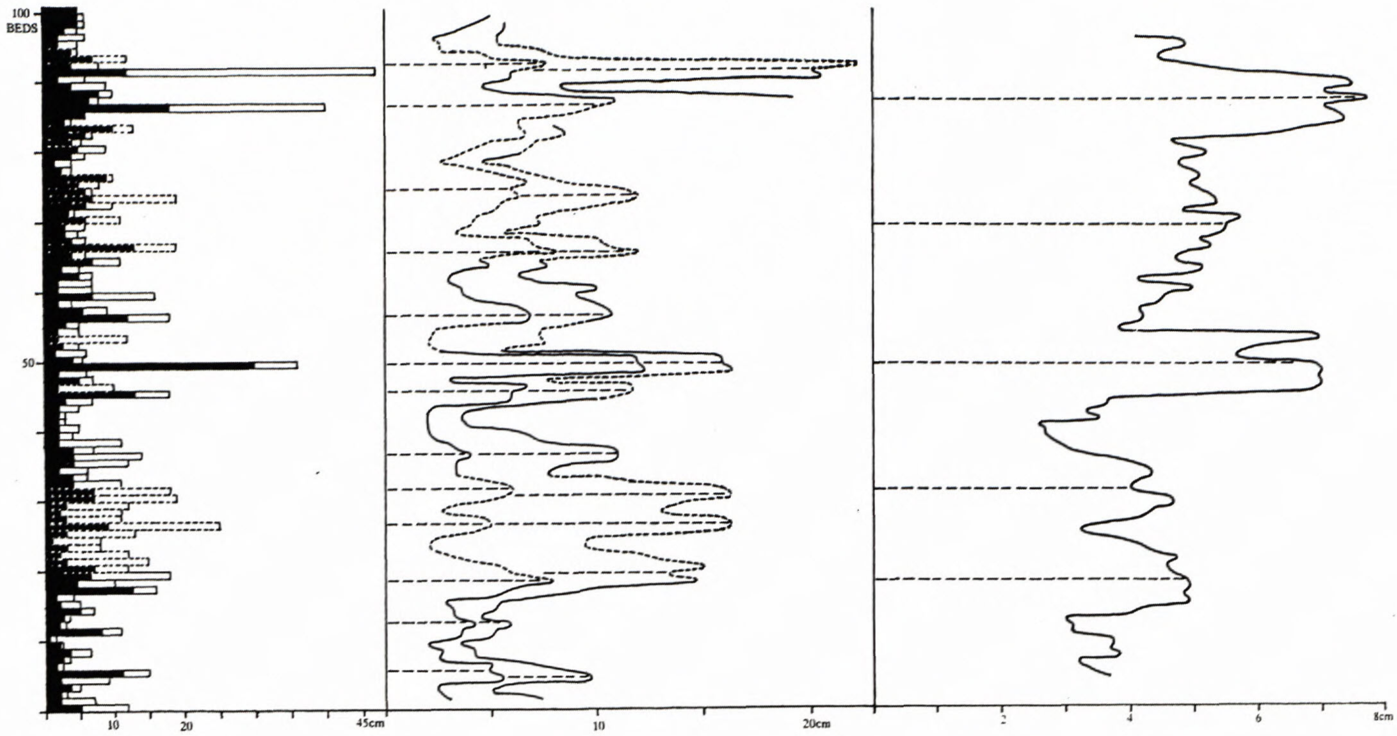


Fig. 7 Hieroglyphic Member of the Rača Subunit. See explanation on fig. 4.

In the outcrops with thin-bedded turbidites there were identified two scale of cycles. The cycles with the approximated duration of 28 to 75 thousand years can be correlated with *5th order sea-level fluctuations* (Tab. 2). They are caused probably by Milankovitch cycles of obliquity.

The more expressive are the cycles with time span 7 to 20 thousand years, which probably correspond with *6th order sea-level fluctuations* (Tab. 2). The origin of them is controlled by Milankovitch cycles of precession.

The inaccuracy between the duration of searched cycles and sea-level fluctuations of 4th, 5th and 6th order is caused the approximate input data for the computing of rate and duration of cycles (Tab. 2). Some of turbidite beds was probably reworked by bottom current to conturites. It could distort the data. Mutti (1992) declares, that the activity of bottom-current in turbidite systems of thrust-fold belts was negligible.

The thin-bedded turbidites are common deposited on the lobe fringe of deep-sea fan. The cycles in them can be also influenced by distributary switching (avulsion) - rearrangement of deposition lobe on deep-sea fan (Shanmugam & Moiola, 1988). Thickness of individual lobe of submarine fan is between 3 and 15 metres. They are composed from medium- to thick-bedded turbidite (Mutti, 1992). After computing the lobes comsist of some tens of beds. It corresponds with 5th and 6th order sea-level fluctuations.

Sun with its cycles plays some role in change of climate. It can be change of sun activity and of orbit around centre of gravity of Sun system (Friedman et al., 1992).

The least *frequency and rate of deposition* (Tab.1) has the Haluszowa Formation (Cebula Member). The frequency of it belongs to low one. The rest tested formations and members have medium frequency of deposition (Einsele, 1992) and have the frequency falling under the interval 1 to 10 thousand years for lower fan and basin plain (Einsele, 1997). The highest rate of deposition was computed at the thick-bedded Kýčera and the Szczawina Members. By the rate of deposition the Haluszowa, the Veselé and the Labowa Shale Formations belongs to continental rise or slope and other tested lithostratigraphic units to deep-sea fan (Einsele, 1992).

Because of simplification there was not taken into account change of frequency in terms of one lithostratigraphic unit. Therefore the obtain results are average values. The frequency of turbidite events depend on the rate of deposition in their source area. Frequent earthquakes, volcanic eruptions or rapid uplift in the source area may shorten time between redepositional event (Klein, 1985). Small and medium-size mountainous rivers of tectonically active setting play a fundamental role in triggering submarine gravity flows and therefore in turbidite sedimentation. (Mutti, 1996). The question of frequency of turbidite events are still open.

Tab. 2 Comparison of Milankovitch cycles with the cycles in the studied area

Order of sea-level fluctuation	causes of fluctuations - Milankovitch cycles and their periodicity (thousand years)	duration of parasequences (thousand years)	lithostratigraphic units	thickness and number of beds in one cycle	approximate duration of cycles (thousand years)
4th	eccentricity 100 & 413	80 - 500	Szczawina Mb. (Rača Subunit)	30 - 180 m (25 - 150 beds)	75 - 600
5th	obliquity 41	30 - 80	Upper Beloveža Mb.	19 - 30 beds	29 - 45
			Hieroglyphic Mb.	13 - 20 beds	29 - 44
			Labowa Shale Fm. - Hieroglyphic Mb.	11 - 30 beds	28 - 75
6th	precession 19 & 23	10 - 30	Upper Beloveža Mb.	5 - 8 (15) beds	7 - 12 (22)
			Hieroglyphic Mb.	4 - 9 beds	9 - 20
			Labowa Shale Fm. - Hieroglyphic Mb.	4 - 8 beds	10 - 20

Conclusion

The cycles of bed thickness and grain size of five orders were identified in the turbidites of the Flysch belt of the Upper Cretaceous to the Upper Eocene age.

The larger and smaller cycles in the schematic lithostratigraphic sections of the Rača and the Bystrica Subunits were well correlated with 2nd and 3rd order sea-level fluctuations. The duration of larger cycles is 13 and 20 and smaller ones 3 to 7 million years. Some parts of the sections were bad comparable because of influence of tectonic movements. Marked disagree with 2nd order fluctuations is probably caused by the Laramian tectonic movements on the border of the Maastrichtian and the Paleocene. Probably in the Paleocene (from the uppermost Maastrichtian) subsidence prevailed over sea-level fall. Very rapid deposition during the Maastrichtian (Szczawina Member - 35 cm per thousand years) and the Upper Eocene (Kýčera Member - 38 cm per thousand years) has probably connection with tectonic uplift of south source area during the Laramian (Maastrichtian) and the Ilyrian (Upper Eocene) phase.

Large amount of glauconite in the Middle Eocene is probably linked with redeposition of glauconite rich sediments deposited during rise of sea-level of the 2nd order on the border of the Paleocene and the Eocene.

The parasequences in the Szczawina Member with time span from 75 to 600 thousand years the most probably correspond with 4th order sea-level fluctuations.

In the outcrops with thin-bedded turbidites there were identified two scale of cycles. The cycles with approximated duration of 28 to 75 thousand years can be correlated with 5th order sea-level fluctuations. The more expressive are the cycles with time span 7 to 20 thousand years, which probably correspond with 6th order sea-level fluctuations. The origin of 4th to 6th sea-level fluctuations is linked with Milankovitch cycle of eccentricity, obliquity and precession.

The less probably explanations for the cycles in thin-bedded turbidites are rearrangement of deposition lobes on deep-sea fan (distributary switching) or some sunny cycles.

From approximate data of the thickness, the duration and average bed thickness of some lithostratigraphic units the frequency and rate of deposition were computed. By the frequency and the rate the deposition during the Campanian (Haluszowa Formation), partly the Veselé and the Labowa Shale Formations has not character of sedimentation on deep-sea fan but on deep-sea slope. Other lithostratigraphic units was probably created on lower part of deep-sea fan or on basin plain.

References

Birkenmajer K. & Oszczypko N., 1989: Cretaceous and Paleogene lithostratigraphic units of the Magura Nappe, Krynica Subunit, Carpathians. An. Soc. Geol. Pol., 59, 117-153.

Bouma A. M., 1962: Sedimentology of some flysch deposits. Amsterdam, Elsevier, 168p.

Cieszkowski M., Oszczypko N. & Zuchiewicz W., 1989: Upper Cretaceous siliciclastic-carbonate turbidites at Szczawa, Magura Nappe, West Carpathians, Poland. Bull. Pol. Acad. Sci., Earth Sci., 37, 231-245.

Einsele G., 1992: Sedimentary Basins. Evolution, Facies and Sedimentary Budget. Springer-Verlag, 628p.

Einsele G., 1997: Event stratigraphy, depositional evens and their control by sediment supply and sea level changes. IAS Lecture Tour, Bratislava.

Faupl P., 1996: Tiefwassersedimente und tektonischer Bau der Flyschzone des Wienerwaldes. Exkursion A2, Exkursionsführer, Sediment 96. Geologische Bundesanstalt, 32p.

Friedman G.M., Sanders J.E. & Kopaska-Merkel D.C., 1992. Principles of Sedimentary Deposits - Stratigraphy and Sedimentology. Wiley, New York.

Golonka J. & Wójcik A., 1978: Szczegółowa mapa geologiczna Polski 1:50000, ark. Jelesnia (wraz z objaśnieniami), Inst.Geol., Warszawa.

Haq B.U., Handerbol J. & Vail P.R., 1987: Chronology of fluctuating sea levels since the Triassic. Science 235, 1156-1167.

Klein G. de V., 1985: The frequency and periodicity of preserved turbidites in submarine fans as a quantitative record of tectonic uplift in collision zones. Tectonophysics 119, 181-193.

Ksiażkiewicz M., 1966: Geologia regionu babiogórskiego. Przew. XXXIX. Zjazdu Pol. Tow. Geol. Inst. Geol., Wyd. Geol. Warszawa.

Lowe D. R., 1982: Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents, J. sedim. Petrol., 52, 279-297.

Malata E., Malata T. & Oszczypko N., 1996: Litho- and Biostratigraphy of the Magura Nappe in the Eastern Part of the Beskid Wyspowy Range (Polish Western Carpathians). An. Soc. Geol. Pol., 66, 269-284.

Malata E. & Oszczypko N., 1990: Deep-water agglutinated foraminiferal assemblages from Late Cretaceous red shales of the Magura Nappe, Polish Western carpathians. In: Paleoecology, Biostratigraphy, Paleooceanography and taxonomy of Agglutinated Foraminifera. Kluwer Academic Publishers, Amsterdam, 507-524.

Matějka A. & Roth Z., 1952: Zpráva o výskumu magurského flyše v povodí Bíle oravy. Věst. Ústř. Úst. geol., 27, Praha, 212-216.

Mitchum R.M.,Jr., 1985: Seismic stratigraphic expression of submarine fan, in Seismic Stratigraphy II, edited by O. R. Berg and D. G. Wolverton, AAPG Mem., 39, 117-138.

Mutti E., 1992: Turbidite Sandstones, Agip S.p.A., Milano, 275p.

Mutti E., 1996a: Facies analysis of turbidite systems. IAS Special Lecture Tour, Brno.

Mutti E., 1996b: Flood-generated sandstone facies in ancient fluvio-deltaic systems. IAS Special Lecture Tour, Brno.

Oszczypko N., Dudziak J. & Malata E., 1990: Stratigraphy of the Cretaceous through Paleogene deposits of the Magura Nappe in the Beskid Sądecki Range, Polish Outer Carpathians. Stud. Geol. Pol., 97, 109-181.

Oszczypko N., 1991: Stratigraphy of the Paleogene Deposits of the Bystrica Subunit (Magura Nappe, Polish Outer Carpathians). Bull. Pol. Acad. Sci., Earht Sci. 39, 4, 415-431.

Oszczypko N., 1992a: Late Cretaceous through Paleogene Evolution of Magura Basin. Geol. Carp., 43, 6, 333-338.

Oszczypko N., 1992b: Zarys stratigrafii plaszczowiny magurskiej (Stratigraphy of the Magura Nappe, Polish Flysch Carpathians. Przewodnik LXIII zjazdu PTG, Krakow, 11-29.

Pesl V., 1968: Litofacie paleogénu v magurské jednotce vnějších flyšových Karpat. Záp. Karpaty, Geol. (Bratislava), 9, 71-117.

Pivko D., 1991: Použitie Markovovho reťazca pri faciálnej sekvenčnej analýze pestrých vrstiev vrchnej kriedy račanskej jednotky na severnej Orave. Geol. práce, Správy 93, 73-79.

Pivko D.,1994: Younger Senonian turbiditic and hemipelagic sediments in the Paleoalpine accretionary belt, Northern Slovakia, Orava. Konferencie, sympóziá, semináre. Annual Assembly IGCP Project. No.362, Abstract book. Geol. úst. D. Štúra, Bratislava, 125-126.

Pivko D., Beňuška P., Korábová K., Kováčik M., Potfaj M., Siráňová Z. & Vranovská A., 1991: Vysvetlivky ku geologickej mape okolia Pilska 1:25 000 na listoch 26-142 Mútne a 26-231 Oravské Veselé. Čiast. záv. správa, MS GÚDŠ Bratislava, 78p.

Posamentier H.W. & Erskine R.D., 1991: Seismic expression and recognition criteria of submarine fans, in Welmer P. & Link M.H. (edit.). Seismic Facies and Sedimentary Processes of Submarine Fans and Turbidite Systems. Springer Verlag, New York, 197-222.

Posamentier H.W. & Vail P.R., 1988: Eustatic controls on clastic deposition II - Sequence and systems tract models, in Wilgus C.K., Hastings B.S., Kendall C.G.St.C., Posamentier H.W., Ross C.A. & Van Wagoner J.C. (edit.). Sea Level Change - An Integrated Approach. Spec. Publ. Soc. Econ. Paleont. Mineral., 42, 125-154.

Posamentier H. W., Jervey M.T. & Vail P.R., 1988: Eustatic controls on clastic deposition I, in Wilgus C.K., Hastings B.S., Kendall C.G.St.C., Posamentier H.W., Ross C.A. & Van Wagoner J.C. (edit.). Sea Level Change - An Integrated Approach. Spec. Publ. Soc. Econ. Paleont. Mineral., 42, 109-124.

Posamentier H.W., Erskine R.D. & Mitchum R.M.,Jr., 1991: Submarine fan deposition within a sequence stratigraphic framework, in Welmer P. & Link M.H. (edit.). Seismic Facies and Sedimentary Processes of Submarine Fans and Turbidite Systems. Springer Verlag, New York, 127-136.

Potfaj M., 1989: Vychylovské súvrstvie - Nová litostratigrafická jednotka v Magurskom flyši (Paleogén Kysúc a Oravy), Regionálna geológia ZK, 25, GÚDŠ Bratislava, 43-49.

Potfaj M., Samuel M., Raková J. & Samuel O., 1991: Geologická stavba Kubínskej hole (Orava). Záp. Karp., geol. 15, 25-66.

Roth Z., 1980: Západní Karpaty - terciérní struktura střední Evropy. Knihovna ÚÚG Praha, 55, 120p.

Ryłko W., 1992: Litostratygrafia osadów płaszczowiny magurskiej w południowo- wschodniej części Beskidu Żywieckiego (Karpaty zewnętrzne). Biul. Inst. Geol., 368, 37-64

Ryłko W., Żytko K. & Rączkowski W., 1992: Objaśnienia do szczegółowej mapy geologicznej Polski, 1:50000, ark. Czadca, Ujsoły. PIG Warszawa, 36p.

Schnabel W.G., 1992: New data on the Flysch Zone of the Eastern Alps in the Austrian sector and new aspects concerning the transition to the Flysch Zone of the Carpathians. Cretaceous Research, London, 13, 405-419.

Shanmugam G. & Moiola R.J., 1988: Submarine fans: Characteristics, models, classifications, and reservoir potential, Earth Sci.Rev., 24, 383-428.

Sikora W. & Żytko K., 1959: Budowa Beskidu Wysokiego na południe od Żywca, Biul.141, Inst.Geol., Warszawa, 60- 204.

Ślączka A. & Miziołek M., 1995: Sytuacja geologiczna warstw ropianieckich w Ropiance (Polskie Karpaty fliszowe). An. Soc. Geol. Pol. 65, 29-41.

Stow D.A.V., 1986: Deep Clastic Seas in Reading H. G. (edit). Sedimentary environments and facies. Blackwell Scientific Publications. Oxford, 399-446.

Švábenická L., Bubík M., Krejčí O. & Stráník Z., 1997: Stratigraphy of Cretaceous Sediments of the Magura Group of Nappes in Moravia (Czech Republic). Geol. Carp., 48, 3, Bratislava, 179-191.

Vail P.R., 1987: Seismic stratigraphic interpretation using sequence stratigraphy, Part 1, Seismic stratigraphy interpretation procedure, in Bally A.W., (edit.). Atlas of Seismic stratigraphy, vol.1. AAPG Stud. Geol., 27, 1-103.

Vail P.R., Audemard F., Bowman S.A., Eisner P.N. & Perez-Cruz C., 1991: The stratigraphic signatures of tectonics, eustacy and sedimentology, in Einsele G., Ricken W. & Seilacher A., (edit.). Cycles and Event in stratigraphy. Springer, Heidelberg new York, 617 -659.

Van Wagoner J.C., Posamentier, H.W., Mitchum, R.M.,Jr. Vail, P.R. Sarg J.F., Loutit T.S., Handerbol, J. 1988: An overview of the fundamentals of sequence stratigraphy and key definitions, in Wilgus C.K., Hastings B.S., Kendall C.G.St.C., Posamentier H.W., Ross C.A. & Van Wagoner J.C. (edit.). Sea Level Change - An Integrated Approach. Spec. Publ. Soc. Econ. Paleont. Mineral., 42, 39-45.

Slovak Geol. Mag. 4, 2(1998), 107–120

Late Eocene - Early Oligocene calcareous nannoplankton and stable isotopes ($\delta^{13}C$, $\delta^{18}O$) of the Globigerina Marls in the Magura Nappe (West Carpathians)

MARTA OSZCZYPKO-CLOWES

Institute of Geological Sciences, Jagiellonian University, Oleandry St. 2a, 30- 063 Kraków, Poland.

Abstract: The Magura Nappe is the largest and innermost unit of the Outer Carpathians. In the Magura Basin sedimentation was completed before the Late Oligocene, whereas in the more external part of the flysch basin sedimentation persisted until the Early Miocene. In the very thick turbidite sequences of the Outer Carpathians, only two regional correlative horizons, associated with condensed pelagic deposits, were recognised. The lower horizon is related to the Cenomanian radiolarian shales and the upper one to the Globigerina Marls at the Eocene/Oligocene boundary. The litho-, biostratigraphy and isotope ($\delta^{13}C$, $\delta^{18}O$) investigations of the Late Eocene/Early Oligocene deposits of the Magura Nappe have been carried out in the following locations: Leluchów in Poland and Raslavice Vyšné - Eastern Slovakia as well as a comparison with the standard section of the Globigerina Marls in Znamirowice (Silesian Nappe, Poland). All samples from the Znamirowice, Leluchów and Raslavice sections contain a fairly abundant calcareous nannoplankton which is assigned to the combine interval zone NP 19-20 (Late Eocene) and to NP 21 (Late Eocene/ Early Oligocene). The uppermost part of the Leluchów section revealed an assemblage belonging to the NP 22 zone. On the basis of stable isotope ($\delta^{13}C$, $\delta^{18}O$) studies, it is possible to make an assumption that during the Late Eocene -Early Oligocene, the Magura Basin was partly isolated from the World Ocean what caused limited circulation of water masses. At the same time, the deposition in the Silesian Basin was still dominated by open marine conditions.

Key words: West Carpathians, Magura Nappe, Eocene-Oligocene boundary, calcareous nannoplankton, pelagic deposits, Globigerina Marls.

Introduction

In the Outer Carpathian flysch basin, with the exception of the Magura sedimentary domain, the Middle to Late Eocene time was a period of unification of the sedimentary condition. During that time hemipelagic and pelagic deep-water sedimentation dominated the Skole, Sub-Silesian, Silesian and Dukla /Fore Magura sedimentary areas (see Książkiewicz (ed.), 1962). At the beginning of Late Eocene, the deposition of the variegated shales was replaced by facies of pelagic green shales. These shales pass upward into the Globigerina Marls which is the most important chronostratigraphic horizon (Bieda et al., 1963; Koszarski, ed., 1985) of the Outer Carpathians. The age of the Globigerina Marls in the Polish Outer Carpathians was determined on the basis of foraminifers (Blaicher, 1961, 1970; Olszewska 1983, 1984; Malata in: Oszczypko *et al.*, 1990).The calcareous nannoplankton of the Globigirina Marls was studied in the Dukla (Smagowicz in: Olszewska & Smagowicz, 1977) and the Silesian Units (Aubry in: Van Couvering *et al.*, 1981).

In the Magura Basin the Early to Late Eocene was a period of a huge facial differentiation. It was manifested by the northward progradation of the fan-lobe system of the Magura Sandstone Formation (Oszczypko, 1992). The Magura Sandstone lithosome was laterally replaced by the thin-bedded Beloveza-like facies and variegated shales of the Łabowa Formation. The Magura Formation is very scarce in the microfauna assemblages which makes difficult to correlate the individual members of this formation (e.g. Poprad and Piwniczna members). These problems could be solved by calcareous nannoplankton studies, which are still at the early stages of development. It is also very important to trace the Globigerina Marls and its equivalents within Upper Eocene and Lower Oligocene lithofacies of the Magura Nappe.

In the Magura Nappe, microfauna of the Globigerina Marls were reported in the Gorlice area (Blaicher & Sikora, 1961) and regarded as an equivalent of the sub-Menilite Globigerina Marls of the Late Eocene age. At the same time the Globigerina Marls were also recognised in the East Slovakian segment of the Magura Nappe (Książkiewicz & Leško, 1959; Nemčok, 1961,

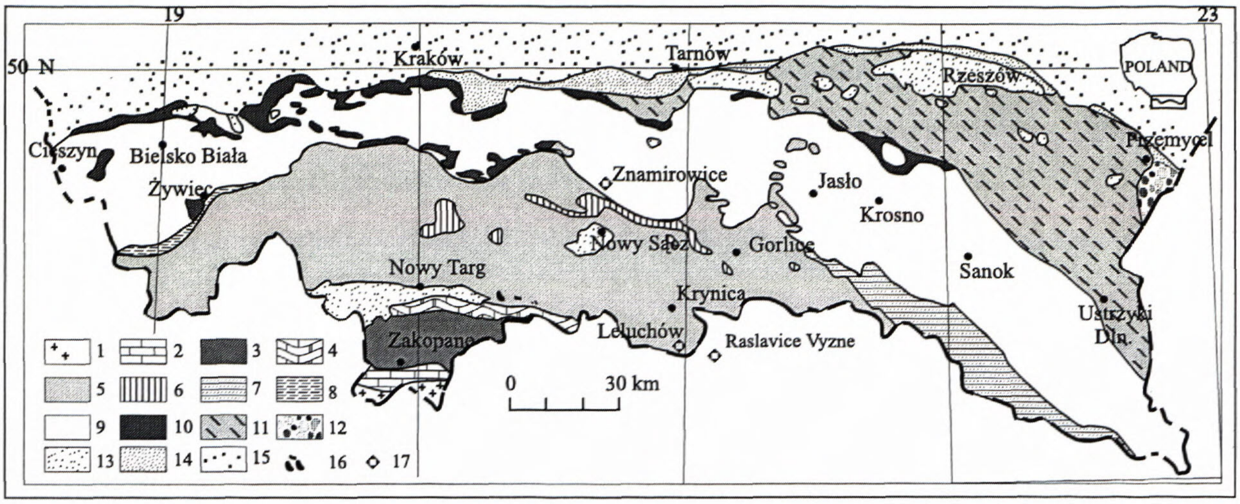


Fig. 1 Geological sketch- map of the Polish Outer Carpathians
1 crystalline core of the Tatra Mts., 2 High Tatra and sub-Tatra units, 3 Podhale flysch, 4 Pieniny Klippen Belt, 5 Magura nappe, 6 Grybów unit, 7 Dukla unit, 8 Fore-Magura unit, 9 Silesian unit, 10 Sub-Silesian unit, 11 Skole unit, 12 Sambor- Rożniatov unit, 13 Miocene deposits upon the Carpathian, 14 Zgłobice unit, 15 Miocene deposit of the Carpathian Foredeep, 16 andesite, 17 investigated area

Świdziński, 1961a). The microfauna of the Globigerina Marls in the Magura Nappe were studied by Malata (Oszczypko et al., 1990), whereas calcareous nannoplankton has been recently studied by Oszczypko M. (1996).

The aim of this work is to prepare litho- and biostratigraphic correlation of the upper Eocene/lower Oligocene deposits in the Magura Nappe from the following locations (Fig. 1): Raslavice Vyšné- East Slovakia (Bystrica Subunit) and Leluchów (Krynica Subunit) as well as a comparison with the standard section of Znamirowice (Silesian Nappe). Additionally the stabile isotope (δ^{13} C, δ^{18}O) analysis from the Leluchów and Znamirowice sections, have been carried out.

Geological setting of the sections

Leluchów. The village of Leluchów is situated in the Poprad Valley (Fig. 1) in the southernmost part of the Magura Nappe, which is close to the Pieniny Klippen Belt (PKB). The upper Eocene-Oligocene deposits are exposed in two places (A and B sections). These sections were studied by Świdziński (1961 b) and Blaicher & Sikora (1967). Recently Birkenmajer & Oszczypko (1989) and Oszczypko *et al.*, (1990) have given a detailed description of these sequences. Section A is located along a path, close to the orthodox church and section B is along a small right tributary of the Smereczek stream.This part of the nappe is represented by a broad (up to 10 km) syncline which is filled with Eocene thick-bedded sandstones of the Magura Formation (see Birkenmajer & Oszczypko, 1989; Oszczypko et al., 1990; Chrząstowski et al., 1995). The syncline is separated from the PKB by a strike-slip fault. In the Leluchów area, the Upper Eocene-Oligocene Malcov Formation overlaps the PKB.

Raslavice. The town of Raslavice (Fig. 1) is located 15 km SE from the Bardejov (E. Slovakia). The examined exposures were situated along the cart-road, about 1 km SW from the Raslavice Railway Station. The Globigerina Marls, exposed in Raslavice, are situated on the south limb of the Ralslavice syncline, which is filled with Malcov Formation (Nemčok, 1961, 1985; Swidziński, 1961 a). According to Swidziński (1961) and Nemcok (1961, 1985) the Raslavice syncline is located along the tectonic contact between Bystrica and Krynica Subunits.

Znamirowice. The Znamirowice (Fig. 1) section displays an exposure of the Globigerina Marls and associated strata of the Silesian Nappe. The examined section is located on the west bank of the Dunajec River in the Rożnów reservoir, about 11 km north from Nowy Sącz.

Lithostratigraphy

Leluchów. The lowest part of the Leluchów sections (A and B) consist of thick-bedded sandstones and conglomerates (Fig. 2). The muscovite sandstones are greybluish in colour and coarse to fine grained, with intercalations of fine-grained conglomerates. The sandstones display T_{abc} Bouma sequences. The thicknesses of the individual beds range from 40 cm to 2,5 m. The infrequent shale-mudstone intercalation are very thin (1-5 cm). Rare 2-5 m thick packets of thin-bedded turbidites are also observed. These deposits belong to the Piwniczna Sandstone Member of the Magura Formation. In both sections (A and B), the contact between the Piwniczna Sandstone Member and the overlying marly shales is not exposed (1-2 m of break in exposure). The marly shales are soft and green with numerous calcite veins with thicknesses varying from 0.5 m (profile A) to 2.5 m (profile B). They are overlain by a 4 m thick marly unit of the

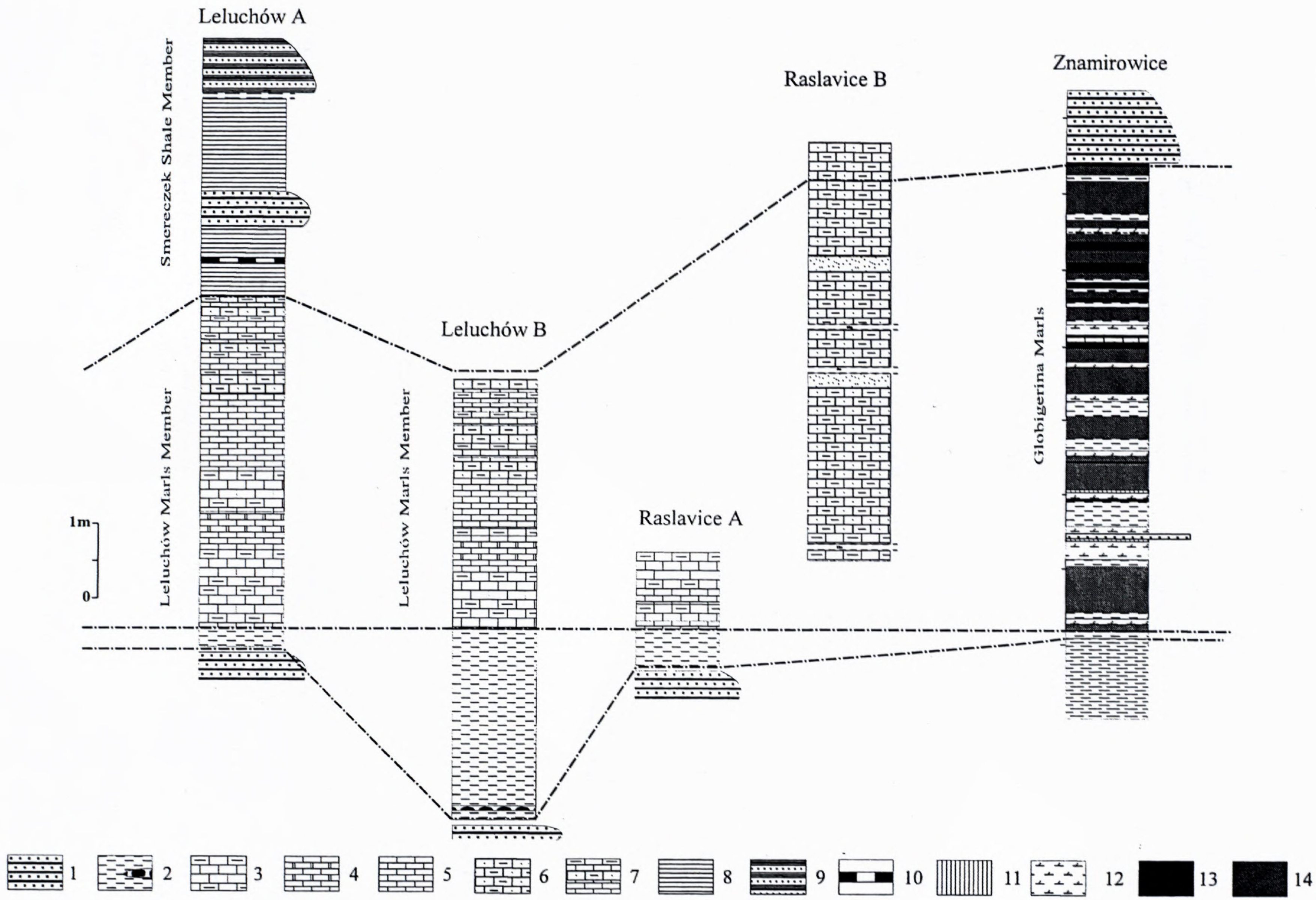


Fig. 2 Lithostratigrafic correlation of Leluchów, Raslavice and Znamirowice sections.
1 thick-bedded sandstones, 2 green calcareous shales, 3 red marls, 4 greyish-green marls, 5 greenish marls, 6 olive marls, 7 grey calcareous marls, 8 Menilite shales, 9 thin-bedded sandstones with shales intercalations, 10 hornstones, 11 limonite, 12 greyish-green non-calcareous shales, 13 dark shales and marls, 14 light-grey marls

Leluchów Marls Member. The sequence of marls is as follows:

- 1 meter of red marls,
- 0.5 meter of greyish-green marls,
- 0.5 meter red marls,
- 1 meter of greenish marls,
- 0.25 meter of olive marls,
- 1 meter of grey calcareous shales.

Just above the calcareous shales, the Smereczek Shale Member is reported (Birkenmajer & Oszczypko, 1989). This member consists of dark bituminous Menilite-like shales with thin (2-5 cm) beds of hornstones. A very thin tuffite bed ("Gąsiory" ? level) was also found in the lower part of the Smereczek Shale Member. In the uppermost part of the Leluchów section, thin-bedded turbidites of the Malcov Formation occur. These flat-laying, south dipping strata consist of Krosno-like, dark-grey marly shales with intercalations of thin bedded (10-12 cm), cross-laminated calcareous sandstones.

Raslavice. The base of section A (Fig. 2) consist of green marly shales (50 cm in thickness) which are overlain by a 85 cm thick marly unit. The sequence of marls is :10 cm of yellowish marls and 77 cm of red marls with 10 thick intercalation of yellowish marls. Section B begins with a 20 cm thick unit of red marls which is followed by 200 cm thick complex of pale marls with a sandstone intercalation at the top. In the uppermost part of the section, a complex of marls with minor sandstone intercalations is exposed. The Menilite Beds reported at this area by Nemcok (1985) have not been found in the examined sections. Going up in the section (towards the Raslavice), the exposures of the Malcov Formation are observed.

Znamirowice. The Globigerina Marls at the Znamirowice section were the subject of detailed research carried out by Van Couvering et al. (1981) and Leszczyński (1996). The section (Fig. 2) begins with a 5-m thick package of green non-calcareous clayey to muddy shales. These sediments pass upwards into a 6.3-m thick package of the Sub-Menilite Globigerina Marls. The base of the Globigerina Marls consist of cream-yellow-beige marls with an alternation of non-calcareous and calcareous green shales. In the uppermost part of Globigerina Marls, the bluish calcareous sandstone occur, which constitutes the bottom part of the Menilite Beds. Few meters above the marls, within the deposits belonging to the Menilite Beds, two thin tuffite layers belonging to the Gąsiory tuffite horizon were found. The fission-track age determination on zircons from the Gąsiory tuffites are: 28.9 +/- 1.2 my for the upper layer and 34.6 +/- 1.4 my for the lower one (Van Couvering *et al.*, 1981). These data indicate the Oligocene age of the Menilite Beds.

Lithostratigraphic correlation

Two sections (Leluchów and Raslavice) out of three described above, belong to the Magura Nappe, whereas, the third one is a part of the Silesian Nappe (see fig. 2). In the lithostratigraphic section of the Magura Nappe, the lowest position is occupied by the variegated shales, known from Raslavice, which are overlain in the Leluchów and Raslavice sections with marly shales and marls belonging to the Globigerina Marls (Leluchów Marls Member; see Birkenmajer & Oszczypko, 1989). In Leluchów just above the marls, dark bituminous shales (the Smereczek Shale Member) and thin- bedded turbidites of the Malcov Formation are reported. However, in the poorly exposed Raslavice section, the red marls are overlain by yellow-grey marls and sandstones belonging to the Malcov Formation. Despite a few differences, the Leluchów Marls Member can be litho- and biostratigraphicly correlated with the Sub- Menilite Globigerina Marls of the Silesian Nappe at Znamirowice.

Studied material and methods

The studied samples were collected by E. Malata and Prof. N. Oszczypko (Leluchów section) and M. Oszczypko-Clowes (Raslavice section). All samples were prepared with the standard smear slide technique for light microscope (LM) observations. The investigations were carried out under LM at magnification of 1024x and 1600x using phase contrast and crossed nicols. Several specimens photographed under SEM and LM are illustrated in figures 3, 4 and 5.

For the purpose of isotopic analyses 14 samples (Leluchów) and 10 samples from Znamirowice (collection belongs to Dr S. Leszczyński) have been used. To isolate the foraminifers, samples were frozen - dried, weighed and desegregated in a Calgon solution. After drying, individual planktonic and benthic foraminifers (see Table 1) were hand-picked from specific size-sorted samples. The stable isotopic analyses were conducted in the Institute of Geochemistry, Mineralogy and Ore deposits of National Academy of Sciences of Ukraine.

Calcareous nannoplankton biostratigraphy and zonation

The most common Paleogene coccolith zonations are the standard zonation of Martini (1971), and the zonation of Bukry (1973), Okada and Bukry (1980). A comparison of these two zonations (Middle Eocene through Lower Oligocene) is presented in Table 2.

The first occurrence (FO) of *Isthmolithus recurvus* DEFLANDRE has traditionally been used as a base of the Upper Eocene. However, this taxon is not a reliable marker in the lower latitudes. The FO of *Sphenolithus pseudoradians* BRAMLETTE et WILCOXON has been also used as a zonal marker for the Upper Eocene. The FO of these species seems to be controversial as the taxon has also been reported in the Middle Eocene (cfr PERCH-NIELSEN, 1985, 1986). The Upper Eocene is therefore no longer considered as two separate zones NP 19 and NP 20, but as a combined zone NP 19- 20 (AUBRY 1983), which is an equivalent to subzone CP 15b (OKADA & BUKRY, 1980). For a long time the last occurrence (LO) of *Discoaster barbadiensis* TAN SIN HOK or *Discoaster saipanensis* BRAMLETTE et RIEDEL was used as a coccolith event, marking the Eocene-Oligocene boundary

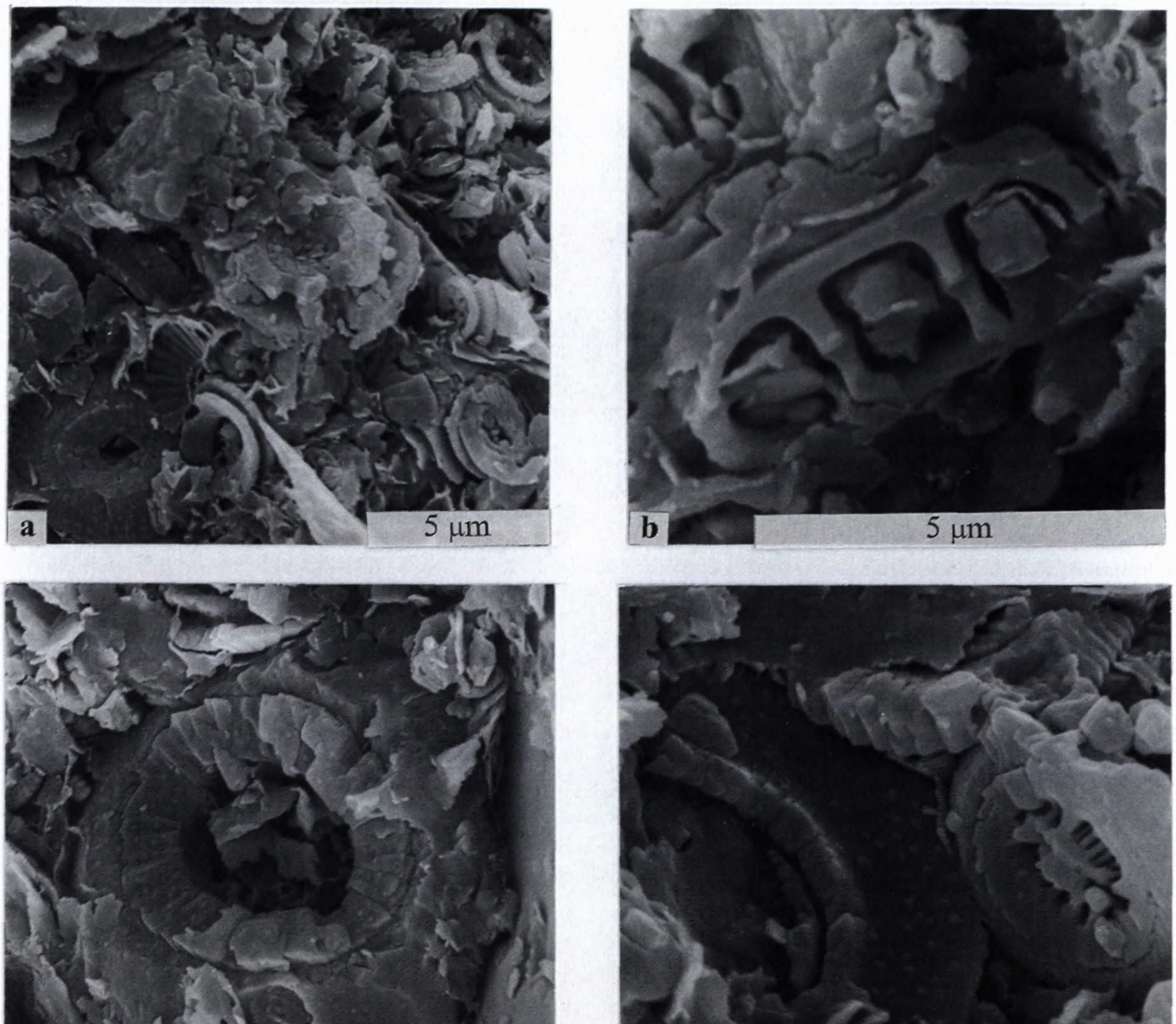
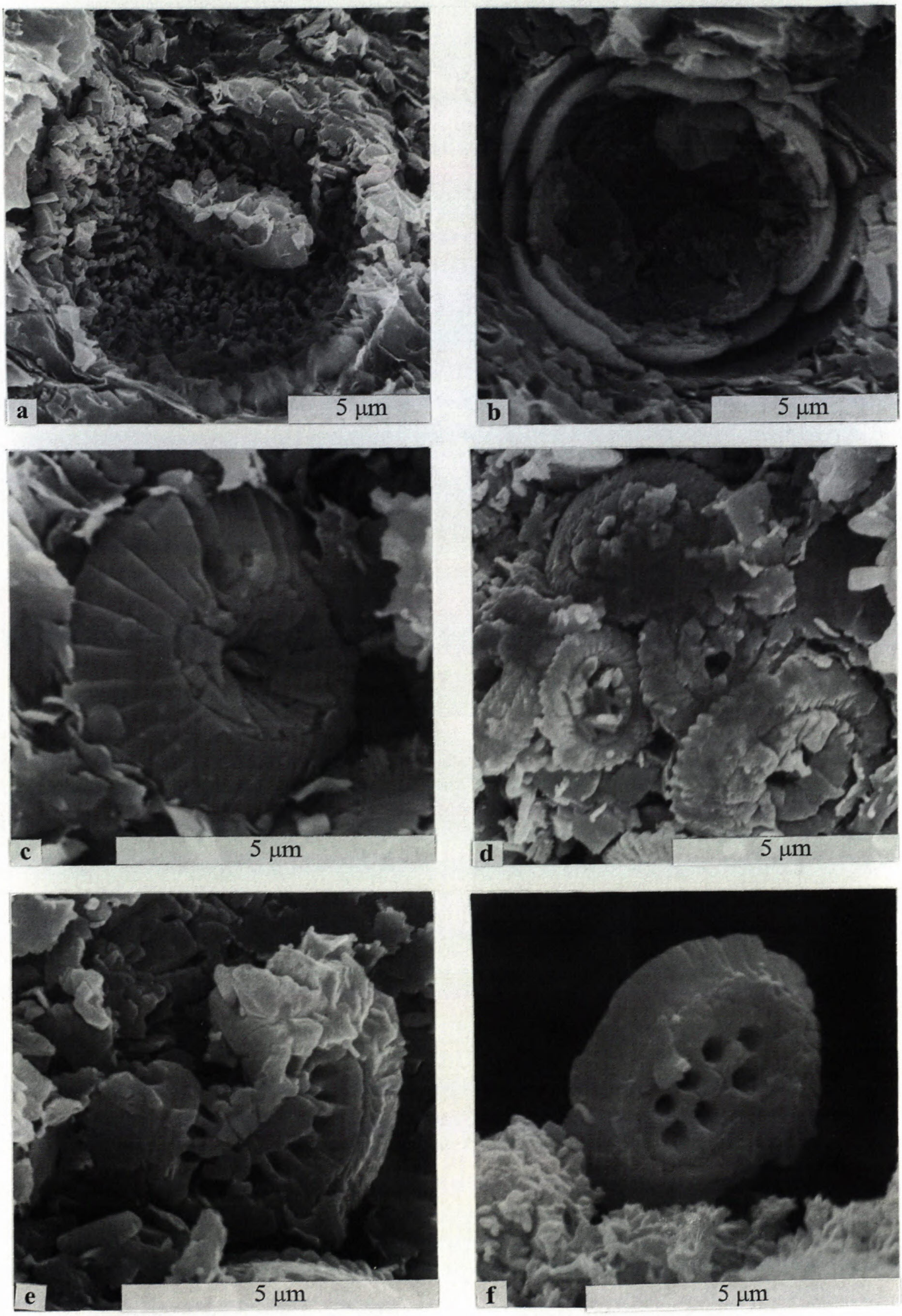


Fig. 3 SEM micrographs

a) rock surface Leluchów, section A, sample 55; b) *Isthmolithus recurvus*, Leluchów, profil A, sample 55; c) *Reticulofenestra hillae*, Leluchów, section A, sample 55; d) *Reticulofenestra umbilica*, Leluchów, section A, sample 55; e) *Dictyococcites callidus*, Leluchów, section A, sample 55; f) *Sphenolithus moriformis*, Leluchów, section A, sample 55


a
5 µm
b
5 µm
c
5 µm
d
5 µm
e
5 µm
f
5 µm

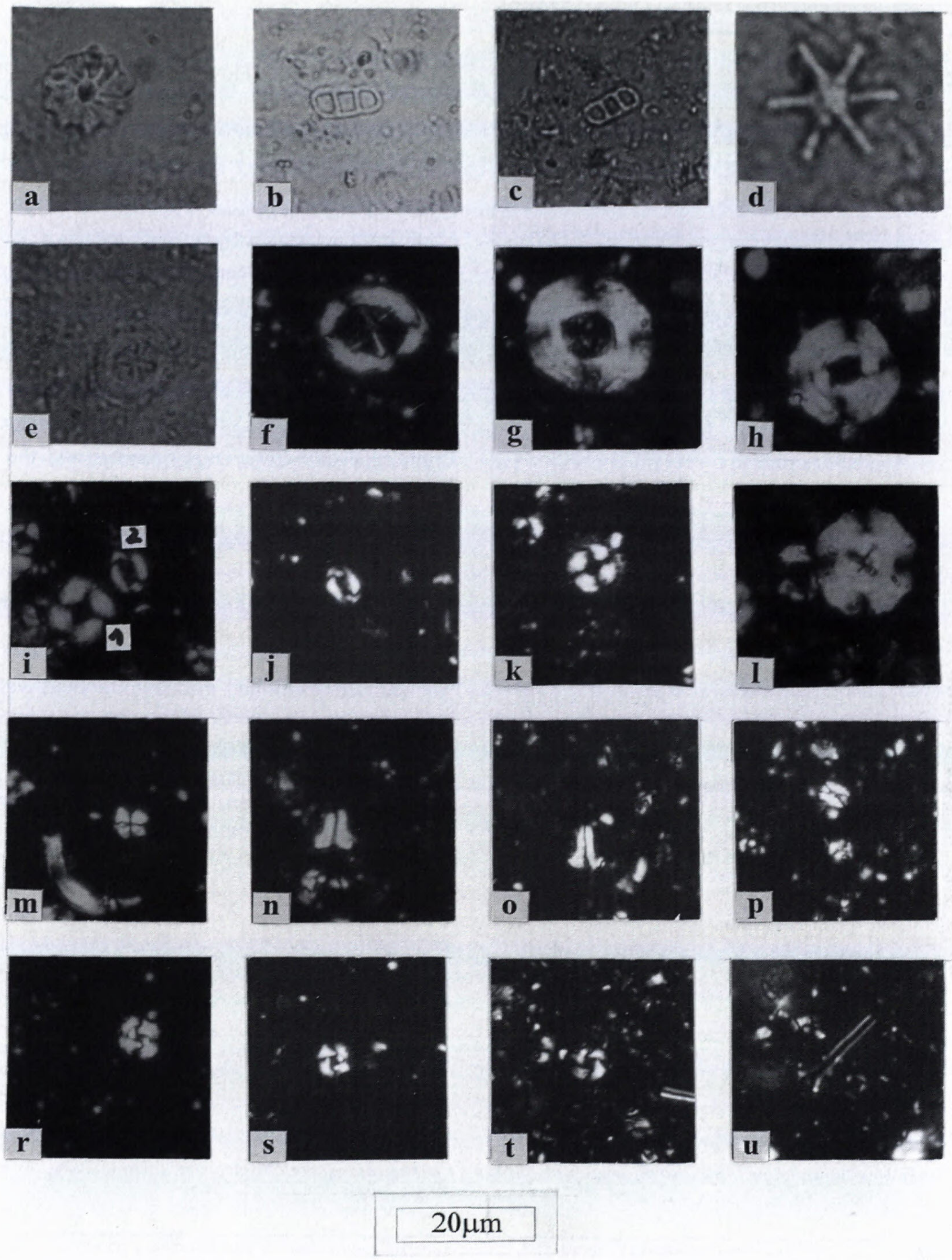


Fig. 4 SEM micrographs

a) *Thoracosphaera operculata*, Leluchów, section A, sample 55; b) Coccosphere of *Dictyococcites bisectus*, Leluchów, section A, sample 55; c) *Coccolithus pelagicus*, Leluchów, section A, sample 55; d) Coccosphere of *Dictyococcites bisectus*, Leluchów, section A, sample 55; ; e) *Dictyococcites callidus*, Leluchów, section A, sample 55; f) *Ericsonia fenestrata*, Leluchów, section A, sample 55

Fig. 5 LM microphotogaphs

a) *Discoaster barbadiensis*, Leluchów, section A, sample 51; b) *Isthmolithus recurvus*, Leluchów, section A, sample 53; c) *Isthmolithus recurvus*, Raslavice section , sample 16; d) *Discoaster nodifer*, Leluchów, section B, sample 36; e) *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; f) *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; g) *Reticulofenestra umbilica*, Leluchów, section B, sample 36; h) *Reticulofenestra hillae*, Leluchów, section B, sample 36; i_1) *Ericsonia formosa*, Leluchów, section B, sample 36; i_2) *Dictyococcites callidus*, Leluchów, section B, sample 36; j) *Dictyococcites callidus*, Raslavice section , sample 19; k) *Ericsonia formosa*, Raslavice section , sample 19; l) *Dictyococcites bisectus*, Leluchów, section A, sample 53; m) *Sphenolithus moriformis*, Leluchów, section B, sample 43; m) *Dictyococcites bisectus*, Leluchów, section B, sample 36; n) *Zygrhablithus bijugatus*, Leluchów, section A, sample 53; o) *Zygrhablithus bijugatus*, Raslavice section, sample 16; p) *Lanternithus minutus* , Raslavice section, sample 16; r) *Cyclicargolithus* ex. gr. *marismontium-floridanus*, Leluchów, section A, sample 55; s) *Cyclicargolithus floridanus*, Leluchów, section A, sample 53; t) *Cyclicargolithus floridanus*, Raslavice section, sample 16; u) *Blackites spinosus*, Raslavice section, sample 16

Sample No	Taxon	$\delta^{18}O$ (PDB)	$\delta^{13}C$ (PDB)
ZNAMIROWICE			
Zn - 5	Globigerina ex. gr. eocena s.l.	-3,75	-3,70
Zn - 6	Globigerina ex. gr. eocena	-3,56	-3,50
Zn - 9	Globigerina div. sp	-3,94	-2,90
Zn - 13	mixed planktonic foraminifers	-4,33	-3,30
Zn - 14	Globigerina div. sp	-4,62	-3,50
Zn - 15	mixed planktonic foraminifers	-4,24	-2,20
Zn - 17	Chilogumbelina sp. (cf. cubensis)	-4,72	-2,70
Zn - 22	mixed planktonic foraminifers	-4,24	-2,80
Zn - 26	mixed planktonic foraminifers	-4,53	-3,70
Zn - 28	mixed planktonic foraminifers	-4,82	-3,90
LELUCHÓW			
L - 36	mixed (Globigerina sp. + Turborotalia sp.)	-7,24	-0,90
L - 37	mixed (Globigerina sp. + Turborotalia sp.)	-6,95	-0,80
L - 38	mixed (Globigerina sp. + Turborotalia sp.)	-6,18	-0,90
L - 40	mixed (Globigerina sp. + Turborotalia sp.)	-5,88	-0,70
L - 41	mixed (Globigerina sp. + Turborotalia sp.)	-6,08	-0,60
L - 42	mixed (Globigerina sp. + Turborotalia sp.)	-5,88	-0,60
L - 44	mixed (Globigerina sp. + Turborotalia sp.)	-6,47	-0,30
L - 45	mixed (Globigerina sp. + Turborotalia sp.)	-5,69	-0,40
L - 46	mixed (Globigerina sp. + Turborotalia sp.)	-5,40	-0,20
L - 48	mixed (Globigerina sp. + Turborotalia sp.)	-5,59	-0,50
L - 50	mixed (Globigerina sp. + Turborotalia sp.)	-5,50	-0,30
L - 51	Eponides div. sp.	-6,00	-0,50
L - 54	mixed (Globigerina sp. + Turborotalia sp.)	-7,05	-0,80
L - 55	mixed (Globigerina sp. + Turborotalia sp.)	-7,47	-0,90

Table I Oxygen and carbon stable-isotope data for planktonic foraminifers from the Leluchów and Znamirowice sections

which coincides with the base of NP 21 (Martini & Ritzkowski, 1968). However, Cavelier (1979) showed that the extinction of *Discoaster saipanensis* and *Discoaster barbadiensis* was diachronous and occurred earlier in the higher latitudes than in the lower ones. It proved that the lower limit of zone NP 21 ranges in age from Late Eocene to Early Oligocene.

For the purpose of this work the standard zonation of Martini (1971) has been used. The detailed biozonal assignments are as follows:

Isthmolithus recurvus/Sphenolithus pseudoradians (NP 19-20) combined zone

Definition: The base of the zone is defined by the first occurrence of *Isthmolithus recurvus* and the top by the last occurrence of *Discoaster barbadiensis* and/or *Discoaster saipanensis*

Author: AUBRY (1983)

Age: Late Eocene

Remarks: This zone is identified in samples from Leluchów section A (48, 49) and B (46, 45, 44, 43) as well as from Raslavice section A (15-19) and B (22-24). The samples examined in this zone yield well preserved and diverse calcareous nannoplankton (Figs. 6, 7, 8) assemblages, characterised by the occurrence of *Isthmolithus recurvus*, *Discoaster barbadiensis*, *Discoaster saipanensis*. Such an association is believed to be indicative of the combined interval zone NP 19-20. *Dictyococcites bisectus* HAY, MOHLER & WADE, *Coccolithus pelagicus* (WALLICH), *Cyclicargolithus floridanus* ROTH & HAY, *Reticulofenestra umbilica* Hay, *Isthmolithus recurvus*, *Ericsonia formosa* (KAMPTNER) are the most commonly recorded species. Species which are also common to lesser extend include *Neococcolithes dubius* (DEFLANDRE), *Reticulofenestra callida* PERCH-NIELSEN, *Lanthernithus minuthus* Stradner, *Zygrablithus bijugathus* (DEFLANDRE).

Table II Calcareous nannoplankton biostratigraphy of the Late Eocene and Early Oligocene (Martini, 1971; Bukry, 1973; Okada & Bukry, 1980)

AGE		BUKRY (1973) ZONE		SUB-ZONE	MARTINI (1971) ZONE	
OLIGOCENE	E	CP 16	*Helicosphaera reticulata*	CP16c	NP 22	*Helicosphaera reticulata*
				CP 16b CP 16a	NP 21	*Ericsonia subdisticha*
EOCENE	L	CP 15	*Discoaster barbadiensis*	CP 15b	NP19-20	*Isthmolithus recurvus*
				CP 15a	NP 18	*Chiasmolithus oamaruensis*
	M	CP 14	*Reticulofenestra umbilica*	CP 14b	NP 17	*Discoaster saipanensis*
				CP 14a	NP 16 & NP 15	*Discoaster tani nodifer*
		CP 13	*Nannotetrina quadrata*	CP 13c CP 13b CP13a		*Nannotetrina fulgens*
		CP 12	*Discoaster sublodoensis*	CP 12b	NP 14	*Discoaster sublodoensis*
	E			CP 12a		

		CALCAREOUS NANNOPLANKTON																																												
SECTION	SAMPLES	Braarudosphaera bigelowii	Chiasmolithus sp.	Chiasmolithus medius	Chiasmolithus oamaruensis	Coccolithus pelagicus	Coronocyclus nitescens	Coronocyclus cf. C. nitescens	Cribrocentrum coenurum	Cyclageleosphaera alta	Cyclicargolithus aff. C. abisectus	Cyclicargolithus floridanus	Dictyococcites sp.	Dictyococcites bisectus.	Dictyococcites callidus	Dictyococcites hesslandii	Discoaster sp.	Discoaster barbadiensis	Discoaster deflandrei	Discoaster saipanensis	Discoaster tani	Discoaster tani nodifer	Ericsonia sp.	Ericsonia cava	Ericsonia formosa	Ericsonia subdisticha	Fasciculithus tympaniformis	Helicosphaera compacta	Helicosphaera euphratis	Isthmolithus recurvus	Lanternithus minutus	Prinsus cf. P. bisulcus	Pontosphaera sp.	Reticulofenestra clatrata/ lockeri	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra reticulata	Reticulofenestra cf. R. reticulata	Reticulofenestra umbilica	Rhabdosphaeraceae indet.	Sphenolithus moriformis	Sphenolithus predistensus	Sphenolithus spiniger	Thoracosphaera operculata	Tranversopontis pulcheroides	Zygrhablithus bijugatus
	55	X		X	X		X		X		X	X	X	X		X	X		X		X	X	X	X		X		X		X	X			X	X		X	X		X	X	X	X	X	X	X
	54						X				X	X		X		X			X											X	X				X	X	X	X	X	X	X	X				X
	53			X		X	X				X	X	X	X		X							X		X	X				X	X			X	X		X	X		X	X	X	X			X
	52		X			X					X	X	X	X		X	X		X		X		X		X	X	X			X		X		X	X	X		X	X	X	X	X	X	X		X
	51					X	X	X		X	X	X	X	X	X	X			X				X		X	X	X		X	X				X	X			X	X	X	X		X	X		X
	50					X		X			X	X	X	X		X	X						X	X	X	X				X				X	X	X	X	X	X	X	X		X	X		X
	49					X	X	X				X	X	X		X	X	X	X	X	X		X	X	X					X					X		X	X	X	X	X			X		X
	48					X	X	X				X	X	X		X	X	X	X	X			X	X	X				X	X			X		X	X	X	X	X	X				X		X

Fig. 6 Distribution of calcareous nannofosils in the Leluchów A section (for further explanation see Fig. 2)

Ericsonia subdisticha zone (NP 21)

Definition: The base of the zone is defined by the last occurrence of *Discoaster barbadiensis* and/or *Discoaster saipanensis* and the top by the last occurrence of *Ericsonia formosa*

Author: ROTH & HAY in HAY et al. (1967), emend. MARTINI (1970)

Age: Early Oligocene (Late Eocene/Early Oligocene cfr. Cavelier, 1979)

Remarks. This zone is identified in samples 20 and 21 in the Raslavice section as well as in samples from Leluchów sections A (50, 51, 52, 53) and B (42, 41, 40, 39, 38, 37). The zone assignment is based on a continuos range of *Ericsonia formosa*, following the disappearance of *Discoaster saipanensis* and *Discoaster barbadiensis*. The described assemblage (Figs. 6, 7, 8) is characterised by the predominance of placoliths over discoasters. Among the asteroliths *Discoaster deflandrei* and *Discoaster tani* are the only species, which were found. Assemblage is abundant in species like *Coccolithus pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Reticulofenestra callida.* The level of reworking is low and represents not more than 7% of the discussed assemblage.

Helicosphaera reticulata zone (NP 22)

Definition: The base of the zone is defined by the last occurrence of *Ericsonia formosa* and the top by the last occurrence of *Reticulofenestra umbilica*

Author: BRAMLETTE & WILCOXON (1967), emend. MARTINI (1970)

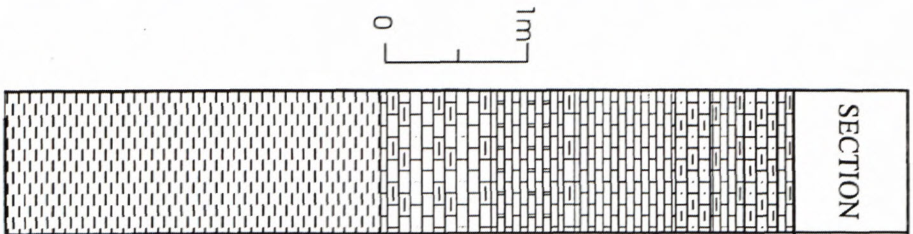
Age: Early Oligocene

Remarks: This zone is identified in samples from Leluchów sections A (54, 55) and B(36). The above mentioned samples contain the poorly preserved calcareous nannoplankton assemblage of low diversity (Figs. 6, 7). The assemblage is dominated by *Cyclicargolithus floridanus, Dictyococcites bisectus, Lanthernithus minuthus* and *Zygrablithus bijugathus* whereas *Reticulofenestra umbilica* and *Isthmolithus recurvus* become very rare.

The formation of Eo- Parathethys

On the basis of stable isotope ($\delta^{13}C$, $\delta^{18}O$) studies, carried out for the Znamirowice and Leluchów sections (Fig. 9), it is possible to reconstruct and compare paleoenviromental condition in the Magura and Silesian basins. The values of stable isotopes ($\delta^{13}C$, $\delta^{18}O$) which were obtain from the Leluchów sections are distinctively

Fig. 7 Distribution of calcareous nannofosils in the Leluchów B section (for further explanation see Fig. 2)



CALCAREOUS NANNOPLANKTON / SAMPLES	46	45	44	43	42	40	41	39	38	37	36
Braarudosphaera bigelowii											X
Chiasmolithus sp.									X	X	X
Chiasmolithus medius											X
Chiasmolithus oamaruensis										X	X
Coccolithus pelagicus	X	X	X	X	X	X	X	X	X	X	X
Coronocyclus nitescens							X		X	X	X
Coronocyclus cf. C. nitescens											X
Cribrocentrum coenurum											X
Cyclicargolithus aff. C. abisectus						X	X	X	X	X	X
Cyclicargolithus floridanus	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites sp.	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites bisectus.	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites callidus											X
Dictyococcites hesslandii	X	X	X	X	X	X	X	X	X	X	X
Discoaster sp.	X	X	X	X		X	X	X	X	X	X
Discoaster barbadiensis	X	X	X	X							
Discoaster deflandrei	X	X	X	X		X	X	X		X	X
Discoaster tani nodifer						X					X
Discoaster saipanensis	X	X	X	X							
Discoaster tani	X	X	X	X		X	X			X	
Ericsonia sp.	X	X	X	X	X	X	X	X	X	X	X
Ericsonia cava										X	X
Ericsonia formosa	X	X	X	X	X	X	X	X	X	X	
Ericsonia subdisticha						X	X	X	X	X	X
Fasciculithus tympaniformis							X		X		
Helicosphaera compacta											X
Helicosphaera dinsenii/ heezenii							X				
Helicosphaera euphratis	X						X				
Isthmolithus recurvus	X	X	X	X	X	X	X	X	X	X	X
Lanternithus minutus					X			X	X		
Reticulofenestra clatrata/ lockeri		X	X	X		X	X	X	X	X	X
Reticulofenestra dictyoda	X	X	X	X	X	X	X	X	X	X	X
Reticulofenestra hillae	X	X	X	X	X	X				X	X
Reticulofenestra reticulata	X	X	X	X	X	X	X			X	X
Reticulofenestra cf. R. reticulata	X		X	X		X	X	X	X	X	X
Reticulofenestra umbilica	X	X	X	X		X	X		X	X	X
Rhabdosphaeraceae indet.	X	X	X	X	X	X	X	X	X	X	X
Sphenolithus moriformis	X	X	X	X	X	X	X	X	X	X	X
Sphenolithus predistensus								X	X	X	X
Sphenolithus spiniger		X	X	X	X	X	X	X	X	X	X
Thoracosphaera operculata	X	X	X		X	X	X	X	X	X	X
Tranversopontis pulcheroides											X
Zygrhablithus bijugatus	X	X	X	X	X	X	X	X	X	X	X

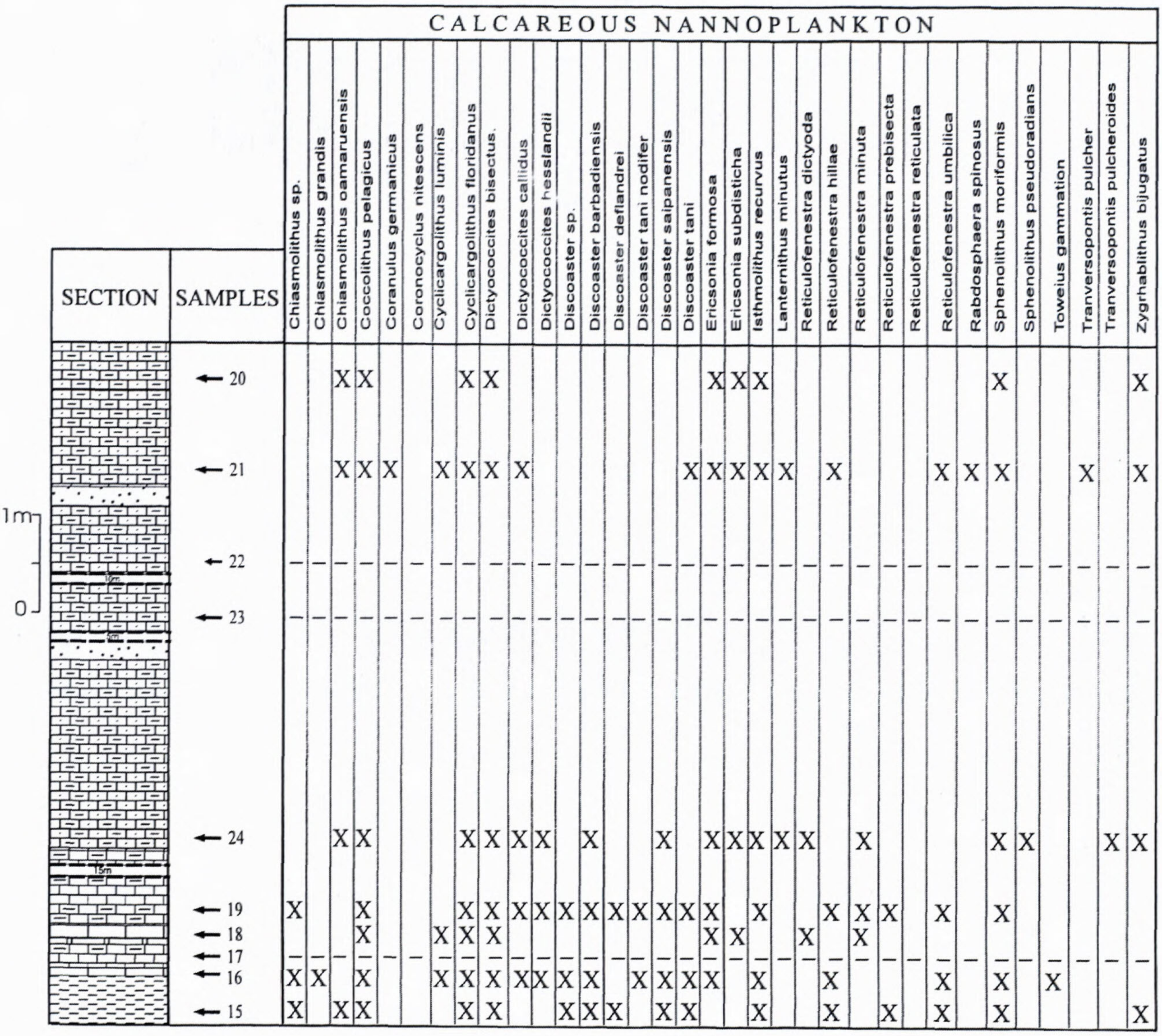


Fig. 8 Distribution of calcareous nannofosils in the Raslavice section (for further explanation see Fig. 2)

different from those gained from Znamirowice. Therefore it may be concluded that during the Late Eocene - Early Oligocene time span, the relatively shallow Magura Basin was partly isolated from the World Ocean what caused limited circulation of water masses. At the same time, the deposition in the Silesian, Sub- Silesian and Skole Basins was still dominated by the open marine conditions.

One of the consequences of the Pyrenean orogeny, was partial isolation of the Northern Thethys from Thethys ss., and formation of the remnant basin so-called Eo- Prathethys (Nagymarosy, 1980). The process of isolation was initiated in the Magura Basin in the Latest Eocene to reach its maximum in the Early Oligocene (during the deposition of the Menilite Shales). In the next stage (Late Oligocene- Early Miocene) the procces of isolation took place in the northern part the Outer Carpathians Flysch Basin (Silesian-Subsilesian, Skole and Boryslaw - Pokuty sub- basins) and came to the end during the Middle Burdigalian (folding and uplifting of the Moldavides, see Oszczypko, 1997).

Discussion

The Globigerina Marls from the Leluchów sections revealed an assemblage belonging to NP 19-20, NP 21 and NP 22 whereas in the previous paper (Oszczypko M., 1996) nannoplankton assemblage of the Globigerina Marls was assigned to the NP 19-20. In the light of new investigations as well as a change in sample preparation, the author decides to determine the following calcareous nannoplankton zones: the combine interval zone NP 19-20 (Late Eocene), NP 21 (Late Eocene/Early Oligocene) and in the uppermost part of the section - NP 22 (Early Oligocene).

The Late Eocene nannoplankton assemblage of the Globigerina Marls is moderately diversified. Haq (1971,

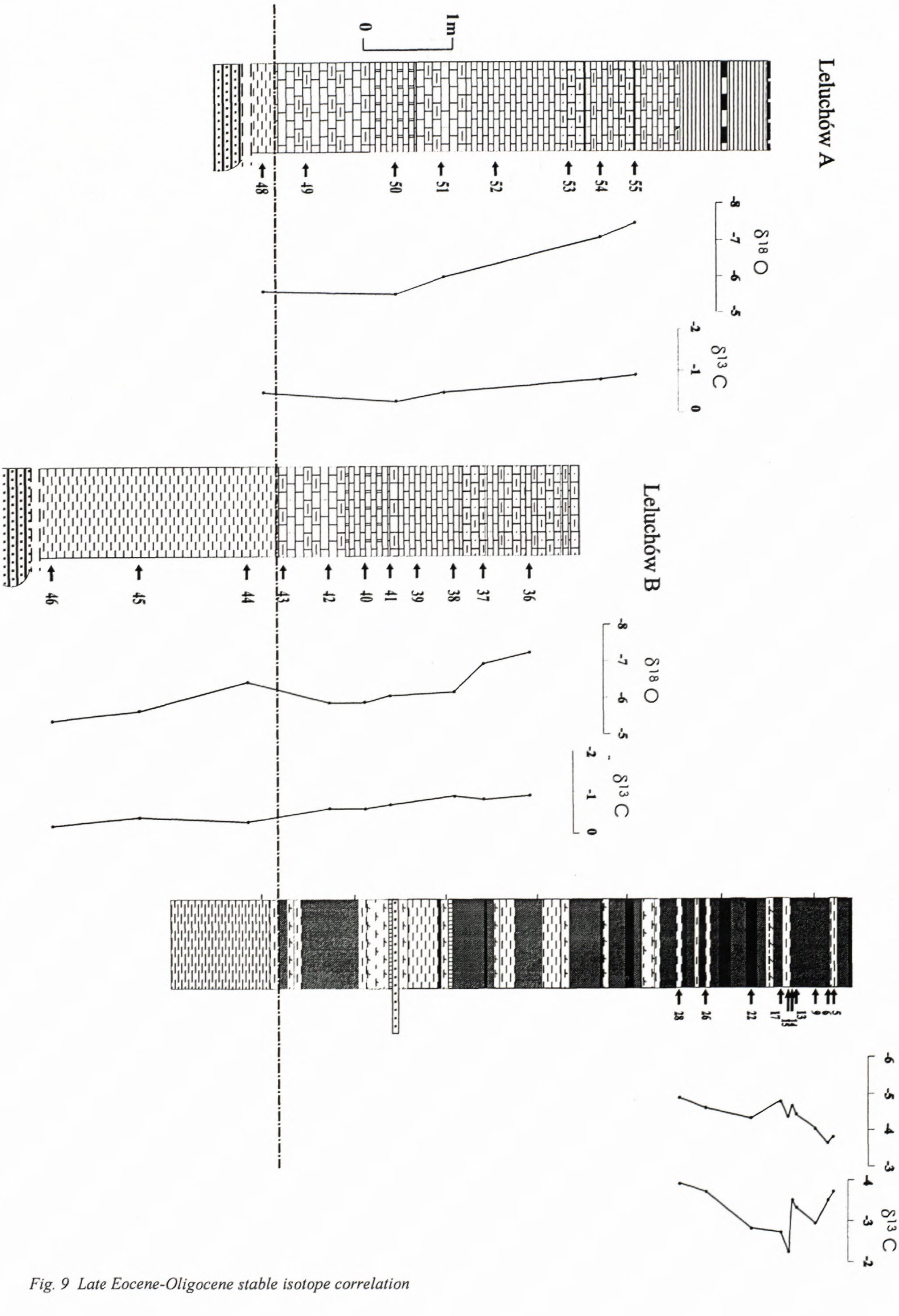


Fig. 9 Late Eocene-Oligocene stable isotope correlation

1973) and Bukry (1978) provided evidence of a strong relationship between calcareous nannoflora diversity and the temperature of the ocean water throughout the Paleogene (see also Andreyeva- Grigorovich & Savickaya, in press). According to those authors the low diversity is associated with a colder temperature and vice versa. Typical cold-water taxa *Isthmolithus recurvus*, *Zygrhablithus bijugatus*, *Lanternithus minutus*, *Chiasmolithus oamaruensis*, *Coccolithus pelagicus*, *Corannulus germanicus*, *Cyclicargolithus floridanus*, *Reticulofenestra reticulata* are dominant forms in the most samples of the upper part of described sections. At the same time the amount of warm-water taxa such as *Reticulofenestra umbilica*, *Discoaster saipanensis* and *Discoaster barbadiensis* is distinctly decreasing towards the top of the Leluchów and Raslavice sectiones. The domination of cold-water, subtropical and moderate latitude taxa coincide with the zone NP 21. These observation corresponds with that reported from the platform domain of South Ukraine, Krime and the Ukrainian Carpathians (Andreyeva-Grigorovich & Savickaya, in press).

Conclusions

1. Despite a few differences in lithology, there is possible to make biostratigraphic correlation of the Leluchów and Raslavice sections (Magura Nappe) with Znamirowice section (Silesian Nappe).

2. The nannoplankton research carried out for the Raslavice and Leluchów sections proved that the Eocene/ Oligocene boundary lies within the Globigerina Marls.

3. The Leluchów Marls Member and the Globigerina Marls in Raslavice differ from the typical Globigerina Marls (Znamirowice section). Beside the grey marls, the Leluchów Marls contain red and green ones which are typically pelagic sediments, enriched in nannofosils. Calcareous nannoplankton assemblages are dominated by taxons from the *Prinsiaceae* family.

4. The samples from the Leluchów and Raslavice sections contain a fairly abundant calcareous nannoplankton, which is assigned to a combined interval zone NP 19-20 and NP 21 of the standard Martini zonation. However, in the uppermost part of the Leluchów section the assemblage of calcareous nannoplankton belonging to the NP 22 has been also determined.

5. The nannoplankton assemblages form the upper portion of the Leluchów and Raslavice sections are dominated by cool-water taxons, which confirm the climatic changes in Late Eocene- Early Oligocene time.

6. The results of stable isotope analysis for the Leluchów section differ distinctively from those obtained in the Znamirowice section. During Late Eocene- Early Oligocene, the Magura basin was partly isolated from the World Ocean what might have caused a limited circulation of water masses.

7. The process of isolation of Silesian-Subsilesian, Skole and Bryslaw-Pokuty sub-basins from Thethys ss. was gradual and took place during the Oligocene and Early Miocene.

Acknowledgements

The author is greatly indebted to Prof. A. Andreyeva-Grigorovich (Lvov University, Ukraine) for fruitful discussion and help offered during investigations: The author is also gratefull to dr Michal Potfaj for his comments on the manuscript. Many thanks to E. Malata for the determination of foraminifers, to Dr S. Leszczyński for giving me the run of his samples from Znamirowice section and to Dr J. Szulc for discussing the stable isotope results. Special thanks are offered to my father for his help during field work as well as for critical remarks on the manuscript. Finally I would like to thank my husband for his help concerning the improvement on the linguistic side of the manuscript . This research was supported by Komitet Badań Naukowych grant No. 6 PO4D 025 11

References

Andreyeva-Grigorovich A., S. & Savitskaya N. A. in press. Fossil Coccolitophorides as indication of the climatic chnages in Eocene Paleobasins of the South region of CIS Algal Journal (in Russian).

Aubry M. P., 1983: Biostratigraphie du Paleogene epicontinental de l'Europe du Nord- Ouest. Etude fondee sur les nannofosiles calcaires. Docum. Lab. Geol. Lyon. 89, 317p. Berger, W. H. & Winterer, E. L., 1974. Plate stratigraphy and the fluctuating carbonate line. In: K. J. Hsu and H. C. Jenkins (eds.), Pelagic sediments on Land and Under the Sea. Int. Assoc. Sedimentol. Spec. Publ., 1: 11-48.

Bieda F., Geroch, S., Koszarski L., Książkiewicz M. & Żytko K., 1963: Stratigraphie des Carpathes Externes Polonaises. Biul. Inst. Geol., 181: 5-174.

Birkenmajer K., & Oszczypko N., 1989: Cretaceous and Paleogene lithostratigraphic units of the Magura Nappe, Krynica Subunit, Carpathians. Ann. Soc. Geol. Polon., 59: 145-181.

Blaicher J., 1961: Mikrofauna margli globigerinowych z rejonu fałdu Podzamcza. Kwart. Geol., 5, 3: 602-612.

Blaicher J., 1970: "Globigerinae" of the Sub- Menilite Globigerina Marls. Biul. Inst. Geol., 21: 137-179.

Blaicher J. & Sikora W., 1961: Próba korelacji wiekowej dolnej granicy warstw magurskich w północnej facji wschodniej części płaszczowiny magurskiej z utworami grupy zewnętrznej. Kwart. Geol., 5, 4: 998-999.

Blaicher J. & Sikora W., 1967: Stratygrafia jednostki rychwałdzkiej w Leluchowie. Kwart. Geol., 11, 4: 453-454.

Bukry D., 1973: Low- Latitude coccolith biostratigraphic zonation. Init. repts. Deep Sea Drill. Proj., 15: 685-703, figs 1, 2.

Bramlette M. N. & Wilcoxon J., 1967: Middle Tertiary calcareous nannoplankton of the Cipero Section, Trinidad. W. I.Tulanne Stud. Geol, 24: 44-60.

Bukry D., 1978: Biostratigraphy of Cenozoic marine sediment by calcareous nannofossils. Micropaleontology, 9: 93-131.

Cavelier C., 1979: La limite Éocene- Oligocene en Europe occidentale. Sci.Géol., Mém., 54: 280 pp.

Chrząstowski J., Nescieruk P. & Wójcik A., 1995: Szczegółowa Mapa Geologiczna Polski 1: 50 000. Arkusz Leluchów. Państ. Instytut Geologiczny. Warszawa.

Haq B. U., 1971: Paleogene calcareous nannoflora. Part IV: Paleogene nannoplankton biostratigraphy and evolutionary rates in Cenozoic calcareous nannoplankton. Stockholm Contr. Geol., 24: 129-158.

Haq B. U., 1973: Transgressions, climatic change and diversity of calcareous nannoplankton. Mar. Geol., 15: M25-M30.

Hay W., Mohler H., Roth P., Schmidt R. & Boudreaux J., 1967: Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area and transoceanic correlation. Trans. Gulf Coast Assoc. gfeol. Soc., 17: 428-480.

Koszarski L. & Koszarski A., 1985: Marginale zone of the Magura Nappe and its relation to lower units. W Koszarski K. (ed): Geology of the Middle Carpathians and Carpathian Foredeep. Guide to Excurs. 3, Carpatho- Balkan Geol. Ass., 13 Congr. (Cracow, Poland 1985) : 1-254. Kraków.

Książkiewicz M. & Lesko B., 1959: On relation between the Krosno- and Magura-Flysch. Bull. Acad. Pol. Sci., Serie Sci. Chim., Geol. et Geogr., 7, 10: 773-780.

Leszczyński S., 1996: Origin of lithological variation in the sequence of the Sub- Menilite Globigerina Marlat Znamirowice (Eocene-Oligocene transition, Polish Outer Carpathians). Annal. Societ. Geolog. Polon., vol. 66: 245-267.

Martini E., & Ritzkowski S., 1968: Was ist das "Unter- Oligocän"? Eine analyse der Beyrisch'schen und V. Koenen'schen fassung der Stufe mit Hilfe des fossilen Nannoplanktons. Akad. Wiss. Göttingen, Nachr., II. Math- Phys. Kl.,1968, 13: 231-250.

Martini E., 1970: Standard Paleogene calcareous nannoplankton zonation. Nature, 226: 560-561, 1 fig.

Martini E., 1971: Standard Tertiary and Quaternary calcareous nannoplnakton zonation, 2: 729-785, pls. 1-4. In A. Farinacci, Proc II Planktonic Conf. Roma 1970, Edizioni Tecnoscienza, Rome.

Nagymarosy A., 1980. From Tethys to Paratethys, a way of survival. Acta Geol. Geoph. Mont. Hung., 25 (3-4) : 373-385.

Nemčok J., 1961: Vznik a výplň depresii v maguskom flyši na vychodnom Slovensku. Geol. Sb. Slov. Akad. Vied, 12:

Nemčok J., 1985. Geologicka mapa Pienin, Cergova, Lubovnianskej a Ondavskej Vyrchoviny, 1: 50 000. Geologicky Ustav Dionyza Stura, Bratislava.

Okada, H. & Bukry D., 1980: Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation. Mar. Micropaleontol., 5 (3), 321-5.

Olszewska B., 1983: Przyczynek do znajomości otwornic planktonicznych podmenilitowych margli globigerinowych w polskich Karpatach zewnętrznych. Kwart. Geol., 27: 546-570.

Olszewska B., 1984: Otwornice bentoniczne podmenilitowych margli globigerinowych polskich Karpat zewnętrznych. Pr. Inst. Geol., 110: 1-37.

Olszewska B. & Smagowicz M., 1977: Porównanie podziałów biostratygraficznych górnej kredy i paleogenu jednostki dukielskiej na podstawie otwornic planktonicznych i nannoplanktonu wapiennego. Przegl. Geol., 25, 7: 359-364.

Oszczypko N., 1973: The geology of the Nowy Sącz Basin (The Middle Carpathians). Biull. Inst. Geol., 273: 101-190.

Oszczypko N., 1992: Late Cretaceous through Paleogene evolution of Magura Basin. Geologica Carpathica, 43, 6: 333-338.

Oszczypko N., 1997. The Early-Middle Miocene Carpathian peripheral foreland basin (Western Carpathian, Poland). Przegl. Geol., 45, 10/2: 1054-1063.

Oszczypko N., Dudziak J. & Malata E., 1990: Stratygrafia osadów płaszczowiny magurskiej (kreda-paleogen) w Beskidzie Sądeckim, Karpaty Zewnętrzne. Stud. Geol. Polon., 97: 109-181.

Oszczypko N. & Wójcik A., 1993. Szczegółowa Mapa Geologiczna Polski, arkusz Nowy Sącz. Państwowy Instytut Geologiczny, Warszawa.

Oszczypko M., 1996: Calcareous nannoplankton of the Globigerina Marls (Leluchów Marls Member), Magura Nappe, West Carpathians. Annal. Societ. Geolog. Polon., vol. 66: 1-15.

Perch-Nielsen K., 1985: Cenozoic calcareous nannofossils, 11: 427-554. In: Bolli H., Saunders J. S. and Perch-Nielsen K., (eds)., Plankton Stratigraphy, Cambridge University Press.

Perch-Nielsen K., 1986: Calcareous nannofossil events at the Eocene-Oligocene boundary. In: Pomerol Ch. & Premoli-Silva I., eds. , Terminal Eocene events. Elsevier: 275-287.

Świdziński H., 1961a: La Serie de Richvald dans les Karpates Flysches. Bull. Acad. Pol. Sci., Ser. des sci. geol. et geogr., 9, 2: 109-119. Warszawa.

Świdziński H., 1961b:. Observations geologiqueus dans les environs de Leluchów, de Plavec. Ibidem: 99-107.

Van Couvering, J. A., Aubry, M. P., Bergeggren, W. A., Bujak, J. P., Naeser, C. W. & Wieser, T., 1981: The Terminal Eocene Event and the Polish connection. Palaeogeograph., Palaeoclimat., Palaeoecol., 36: 321-362.

Slovak Geol. Mag. 4, 2(1998),121–136

Carnian spire-bearing brachiopods from the Slovak Karst (SE Slovakia)

MILOŠ SIBLÍK

Geological Institute of the Academy of Sciences of the Czech Republic, Rozvojová 135, 165 00 Praha 6-Suchdol

Abstract: Koninckinacean, spiriferid and athyridid brachiopods are dealt with in this paper, which is the last contribution to the taxonomic study of the Carnian brachiopod fauna of the Slovak Karst. Based on internal characteristics, the generic affiliation of *"halobiarum"* BITTNER to *Spiriferina* has been changed and the species is referred now to *Mentzelia* QUENSTEDT: *Laballa dagysi* is described here as a new species, and *Mentzelia halobiarum versata* as a new subspecies. The latter is a further taxon characteristic of the upper brachiopod assemblage in the local Carnian.

***Key words*:** Western Carpathians, Slovak Karst, Triassic, brachiopods

Introduction

This paper focuses on spire-bearing brachiopods = *Koninckinidae, Spiriferida* and *Athyridida*= groups that formerly were all classified in *Spiriferida.* It is the final part of my detailed study of the Carnian brachiopod fauna from the Slovak Karst. The study was based on large collections made during the last 4 decades, in the beginning by J. Bystrický and his collaborators, and later sampled also by myself. The general geological situation was referred to in my previous papers on the brachiopod fauna (e.g. Siblík,1986), the exact location of the fossil localities is well documented from the sketches in papers by Kochanová and Kollárová-Andrusovová (1983) for Silická Brezová and its environs, and by Kochanová (1987) for the Ostré vŕšky area. A small brachiopod collection was made in a recently excavated trench SSE of the old quarries near Silická Brezová.

Acknowledgements:

This research was made possible thanks to the grant from the Grant Agency of the Academy of Sciences of the Czech Republic (grant no. A 3013606). Short visits to Vienna enabling study of comparative material were financially supported in 1996 and 1997 by the Austrian Academy of Sciences. Dr. Fr. Stojaspal (Geologische Bundesanstalt, Wien), Dr. H. Summesberger (Naturhistorisches Museum, Wien), and Prof. Dr. L. Krystyn (Institut für Paläontologie, Univ.Wien) kindly provided access to collections and loaned comparative material. I am also indebted to Ing. M. Rozložník (Manager of the Protected Landscape Region - the Biospheric Reserve Slovak Karst, Brzotín) for his kind assistance and permission to continue sampling. I owe thanks also to Prof. A. Dagys (Vilnius) who examined my material of *Laballa* and encouraged me to establish the new species.

Systematic description

Order: *Strophomenida* ÖPIK 1934
Superfamily: *Koninckinacea* DAVIDSON, 1853
Family: *Koninckinidae* DAVIDSON, 1853

The koninckinids are very common in the light-coloured coquina "Tisovec" Limestone in the environs of Silická Brezová. Their preservation is commonly unsatisfactory, however. Except for 2 complete specimens, only pedicle valves (in most cases their internal moulds) have been found. Many of them are fragmentary or damaged in their posterior parts. In the absence of information on internal details, one must consider general shape and some external characters only. Recognition of species is, thus, made rather difficult and a considerable part of koninckinid material could not be well identified specifically. The comparative material in Vienna is not numerous and its preservation rather mediocre. In his recent paper, Dagys (1996) established a new suborder *Koninckinidina* and included it in *Athyridida.*

Koninckina SUESS in DAVIDSON, 1853

***Koninckina* cf. *alata* BITTNER, 1890**
(Pl. 1, Fig. 1)

cf. 1890 *Koninckina alata* nov. spec. - BITTNER, p. 236, Pl. 16, Fig. 17.

Material: One slightly damaged pedicle valve measuring 9.6x 10.4 mm.
Remarks: The specimen is similar to *Koninckina alata* as figured by BITTNER (1890) though the "ears" cannot be

adequately compared since they have been damaged in my specimen. It differs from Bittner´s type in its greater convexity. Similarly, a more convex valve determined as *Koninckina alata* was figured by JIN & FANG (1977, Plate 4, Fig. 4).

Occurrence: Silická Brezová - lower part of Balog´s locality. *Koninckina alata* was described from the Dinarids (Norian).

***Koninckina* cf. *strophomenoides* BITTNER, 1890**

cf. 1890 *Koninckina strophomenoides* ZUGMAYER (in coll.) nov. spec. - BITTNER, p. 235, Pl. 16, Fig. 16.

Material: 1 fragmentary pedicle valve without anterior and anterolateral margins (inv. no. SNM Z 21995).

Remarks: The fragment resembles Norian *Koninckina strophomenoides* BITTNER by its dimensions, flat character, slight beak and very long, straight hinge line. A poorly developed concentric ornament is visible near lateral margin of valve. The definite specific determination is made difficult owing to poor preservation.

Occurrence: Silická Brezová - lower part of Balogh 's locality.

Carinokoninckina JIN & FANG, 1977

***Carinokoninckina telleri* (BITTNER, 1890)**

(Pl. 1, Figs. 4-5)

1886 *Koninckina Telleri* n. sp. - BITTNER, p. 5 (nomen nudum).
1890 *Koninckina Telleri* BITTNER. nov. spec. - BITTNER, p. 129, 131, 134, Pl. 30, Figs. 1-10 (incl. var. *ornata* and *dilatata*).
1963 *Koninckina telleri* BITTNER - DAGYS, p. 134, Pl. 21, Figs. 3-4.
1974 *Koninckina telleri* BITTNER - DAGYS, Pl. 26, Fig. 2.
1988 *Koninckina telleri* BITTNER - SIBLÍK, p. 24.

Lectotype (selected by Siblík, 1988): BITTNER, 1890, Pl. 30, Fig. 5. It is deposited in the Geologische Bundesanstalt, Wien (no.1890/2/150).

Locus typicus: Oberseeland (Zgornje Jezersko), Slovenia.

Stratum typicum: Carnian (according to DIENER, 1920, p. 77).

Material: 66 mostly fragmentary internal moulds of pedicle valves. The dimensions of figured specimens: 10.3 x 13.0 mm (Pl.1, Fig. 4) and 9.5 x 10.6 mm (Pl. 1, Fig. 5).

Remarks: Most specimens show a considerable resemblance to those figured by BITTNER (1890) on Pl. 30, Figs. 4, 6 but differ from them in lesser thickness and lesser convexity of pedicle valves. However, some other Bittner's specimens of *"telleri"* deposited in the collections of the Geologische Bundesanstalt in Vienna have pedicle valves of lesser thickness, and these are comparable to my specimens. Larger, sulcated specimens similar to that figured by BITTNER on Pl. 30, Fig. 10 (as var. *dilatata)* are found only exceptionally in my material. *Koninckina telleri* was quated from the Slovak Karst already by BYSTRICKÝ (1964). This determination was called partially in question by SIBLÍK (1997), but afterwards it was confirmed during the study of comparative material of *"telleri"* and *Koninckina leopoldiaustriae* in the Geologische Bundesanstalt in Vienna. *Koninckina telleri* became the type species of *Carinokoninckina* JING & FANG, 1977.

Occurrence: Silická Brezová - lower part of Balogh 's locality (38 specimens), upper part of Balogh's locality (3 specimens), M-45 (2 specimens), 60 m ESE of M-49 (3 specimens), loc.Šimák near the elevation point 419.3 (11 specimens), Ostré vŕšky - loc. B_2A (8 specimens, 3 of them var. *dilatata* BITTNER), loc. O_2 (1 specimen).

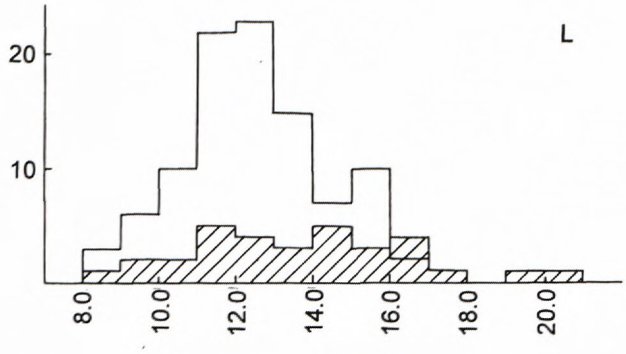


Fig. 1 Length frequency histogram for 99 specimens of *Mentzelia halobiarum halobiarum* (BITTNER) (Ostré vŕšky Hill. loc. B_2A) and 32 specimens of *Mentzelia halobiarum versata* ssp.n. - hatched (Silická Brezová - upper part of Balogh´s locality), in mm. Vertically number of specimens.

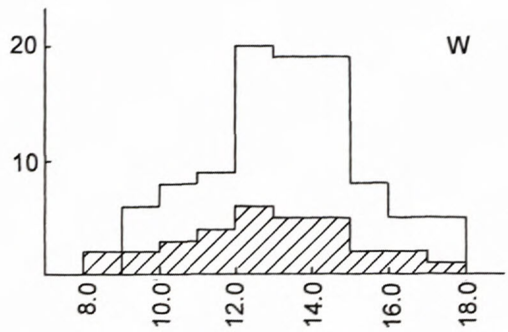


Fig. 2 Width frequency histogram (for explanation see Fig. 1).

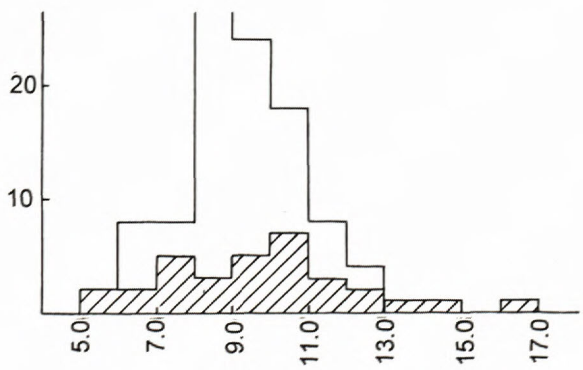


Fig. 3 Thickness frequency histogram (for explanation see Fig. 1).

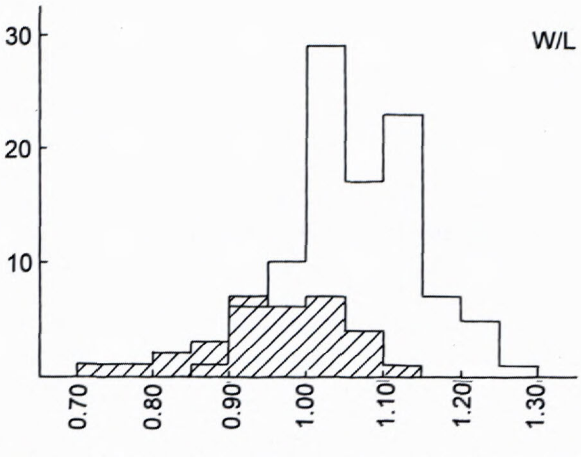


Fig. 4 Width/length frequency histogram for 99 specimens of *Mentzelia halobiarum halobiarum* (BITTN.) (Ostré vŕšky Hill, locB_2A) and 32 specimens of *Mentzelia halobiarum versata* ssp.n.- hatched (Silická Brezová - upper part of BALOGH's locality), in mm. Vertically number of specimens.

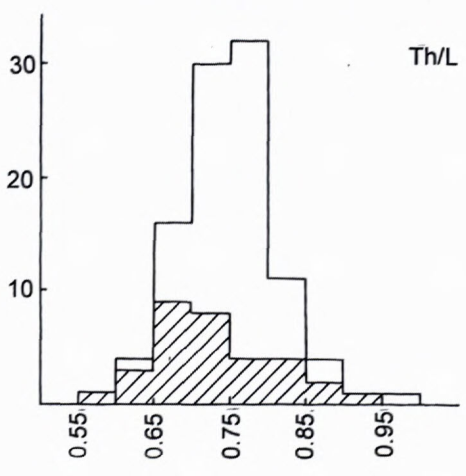


Fig. 5 Thickness/length frequency histogram (for explanation see Fig. 4).

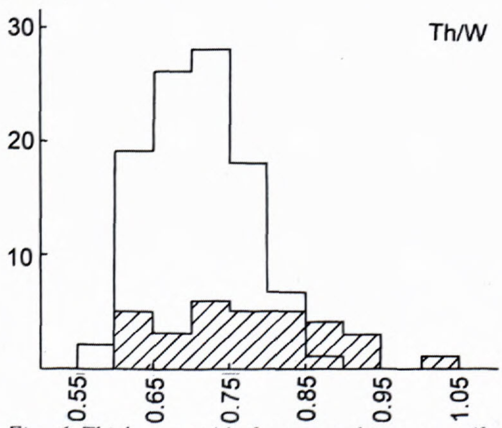


Fig. 6 Thickness/width frequency histogram (for explanation see Fig. 4).

***Carinokoninckina* aff. *expansa* (BITTNER, 1890)**
(Pl. 1, Fig. 2)

aff. 1890 *Koninckina expansa* nov. spec. - BITTNER, p. 132, 134, Pl. 30, Figs. 11 - 12.

Material: 45 fragmentary specimens. The figured one has dimensions 10.0 x 13.0 mm.
Remarks: There is a series of pedicle valves with weakly developed umbonal parts bearing certain resemblances to Carnian *Carinokoninckina expansa* figured by BITTNER (1890) on Pl. 30, Fig. 12. They are in average smaller and many are thicker, more convex, and have longer hinge lines. Owing to the limited number of well-preserved specimens of this variable material, it was not possible to determine it precisely. Bittner 's variety *crassitesta* (1890, Pl. 30, Fig. 11) was distinguished by Bittner from "*expansa*" by its much thicker shell material and by longer hinge line.
Occurrence: Silická Brezová - lower part of Balogh 's locality (23 specimens), upper part of Balogh 's locality (2 specimens), M-45 (2 specimens), 60 m ESE of M-49 (18 specimens).

Order: *Spiriferinida* IVANOVA, 1972
Suborder: *Spiriferinidina* IVANOVA 1972
Superfamily: *Mentzelioidea* DAGYS, 1974
Family: *Mentzeliidae* DAGYS, 1974
Subfamily: *Mentzeliinae* DAGYS, 1974
Mentzelia QUENSTEDT, 1870

***Mentzelia halobiarum* (BITTNER, 1890)**
(Pl. 1, Fig. 6, Pl. 2, Figs. 1-5, Pl. 3, Fig. 2, Pl. 4, Fig. 5, Text-Figs. 1-8, 10B)

1890 *Spiriferina halobiarum* nov.spec.- BITTNER, p. 248, Pl. 14, Figs. 6-15 (incl. var. *linguata*).
?1890 *Spiriferina halobiarum* var. *amblyrhyncha* - BITTNER, p. 248, Pl. 14, Fig. 16.
1972 *Spiriferina halobiarum* BITTNER - ENTCHEVA, p. 23, Pl. 6, Figs. 7-8.
1988 *"Spiriferina" halobiarum* BITTNER - SIBLÍK, p. 70 (cum syn).
? 1993 *"Spiriferina"* cf. *halobiarum* BITTNER - GYALOG et al., p. 183, Pl. 2, Fig. 3.

Lectotype (selected by SIBLÍK, 1988): BITTNER, 1890, Pl. 14, Fig. 7, deposited in the Geologische Bundesanstalt in Vienna (no. 1890/2/329).
Locus typicus: Bergstein near Landl/Enns, Styria.
Stratum typicum: Hallstatt Lms., Carnian.
Material: 192 complete specimens, 19 brachial and 99 pedicle valves. Specimens have been observed up to about 17.5 mm in length, 18.0 mm in width and 13.0 mm in thickness. The figured specimens measure: 9.1 x 9.6 x 6.8 mm (Pl. 1, Fig. 6), 16.3 x 18.4 x 11.3 mm (Pl. 2, Fig. 1), 17.2 x 17.9 x 12.7 mm (Pl. 2, Fig.2), 13.8 x 14.9 x 9.6 mm (Pl. 2, Fig. 3), 12.5 x 13.2 x 9.0 mm (Pl. 2, Fig. 4), 13.8 x 13.8 x 10.3 mm (Pl. 2, Fig. 5), 16.1 x 14.9 x 11.5 mm (Pl. 3, Fig. 2), 13.8 x 15.4 xs 10.2 mm (Pl. 4, Fig. 5).
Internal characters: Interior of the pedicle valve has striate cardinal process and median septum of variable length. Median septum fused with low dental flanges to form spondylium-like structure which makes generic affiliation of "*halobiarum*" to *Mentzelia* evident. Septum not continuing into spondylial cavity in some sectioned spe-

cimens. In rare cases, short ventral adminicula partly separated from median septum were ascertained near to umbo. Analogous development could be stated also in some specimens of *Mentzelia halobiarum versata* ssp.n. (see Fig. 10 C-D). Similar observations were described and figured in some mentzeliids *(Mentzelia mentzelii, Mentzelia sinuata, Koeveskallina koeveskalliensis)* by DAGYS (1974, p. 28, Fig. 7). At the same time, he associated *"halobiarum"*, with some hesitation, to his new genus *Mentzelioides* (DAGYS, 1974, p. 131). The separation of adminicula from septum could formerly be - when observed on the outer shell surface - the cause of illusory "tripartite" character of *"halobiarum"* reported in his original description by BITTNER (1890).

Except for massive teeth and subparallel hinge plates, the infilling of crystalline calcite made it impossible totrace other internal structures in sectioned specimens.

Remarks: The great external variability of the species was previously emphasized by BITTNER in his original description (1890). Width of area belongs, according to him, to the most variable characters of *"halobiarum"*. Most of specimens from the Slovak Karst differ from the Austrian ones in having a shorter hinge line, and thus, in more rounded outline of the shell. There are, however, Austrian specimens that also develop a short hinge line (e.g. BITTNER, 1890, Pl.14, Fig.12, or the specimen from Balbersteine/Miesenbach figured herein on Pl. 3, Fig. 5). Only a few of my specimens show faint, poorly ascertainable ribbing close to the outer parts of valves; the majority of individuals remain completely smooth. Most specimens in the upper part of Balogh's locality near Silická Brezová, is represented by larger single valves without any ribbing and without stronger sulcation or folding. They are classified without any hesitation with the species under consi-

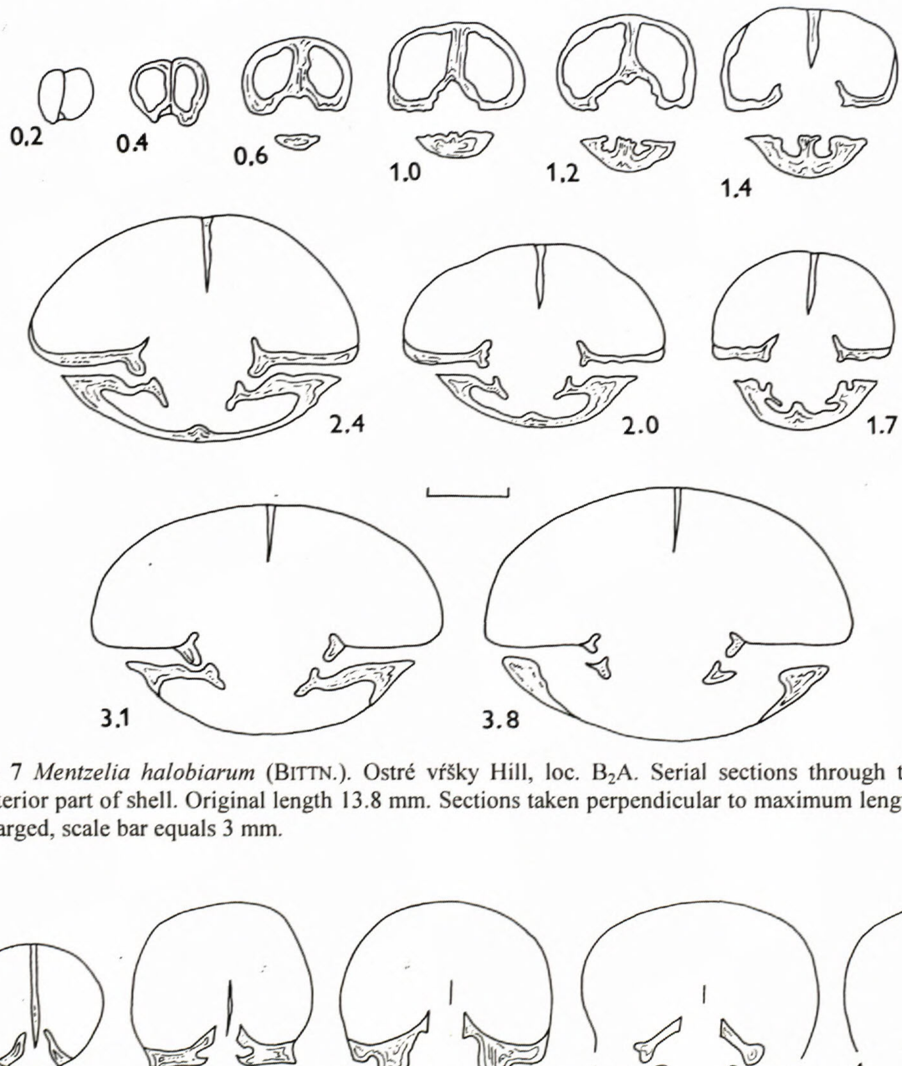


Fig. 7 *Mentzelia halobiarum* (BITTN.). Ostré vŕšky Hill, loc. B_2A. Serial sections through the posterior part of shell. Original length 13.8 mm. Sections taken perpendicular to maximum length. Enlarged, scale bar equals 3 mm.

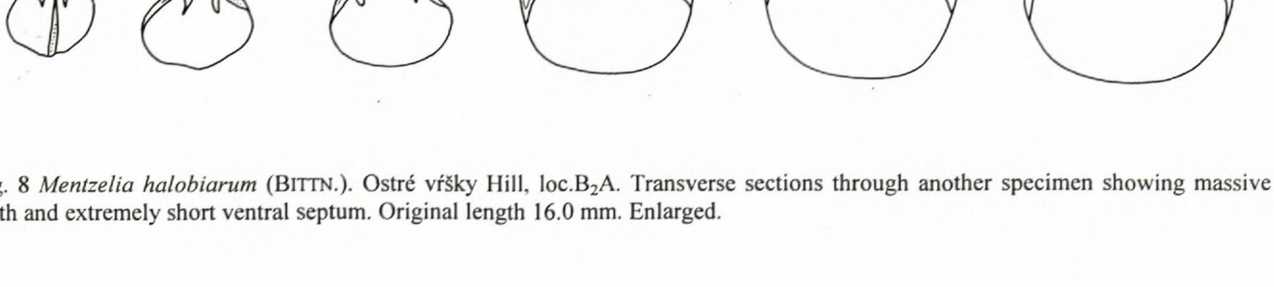


Fig. 8 *Mentzelia halobiarum* (BITTN.). Ostré vŕšky Hill, loc.B_2A. Transverse sections through another specimen showing massive teeth and extremely short ventral septum. Original length 16.0 mm. Enlarged.

deration. *Mentzelia halobiarum* shows considerable affinity to *"Spiriferina" ptychitiphyla* BITTNER from the Anisian Schreyeralm Limestone except that this latter species has a better defined and laterally limited fold and deep sulcus. Already PEARSON (1977, p. 19) proved that *"ptychiphila"* is a true mentzeliid,and it was confirmed also by my study of a specimen from Schiechlinghöhe near Hallstatt which revealed a well- developed spondylium and bilobate cardinal process.

The affirmation of the Norian occurrence of the species could be based on the material coming from the Hallstatt Limestone and deposited in two Vienna institutions: two specimens in the possession of the Palaeontological Institute of the University (coll. Gruber) originate from Balbersteine/Miesenbach (Lower Austria) - Lacian 1. The first a globose specimen with subangular anterior plication is figured herein on Pl. 3, Fig. 5, and the other is a smooth one (width 34.0 mm) closely resembling Bittner 's specimen (1890, Pl. 14, Fig. 9) in outline and in well-developed sulcation of the pedicle valve. Also of Norian age, are 2 smooth specimens with shallow sulcation from Steinbergkogel near Hallstatt, deposited in the collections of the Naturhistorisches Museum (no. 1926. II. 213, coll. Heinrich).

Occurrence: Carnian - Norian of the Northern Calcareous Alps. The species was reported also from the Tisovec Lms.at the Spalenisko locality near Dobšinská ľadová jaskyňa in the Stratenská hornatina Mts. (Pevný in Bystrický et al., 1982). My material comes from the following localities: Silická Brezová - lower part of the Balogh 's locality: 19 specimens (1 complete specimen, 1 brachial valve and 17 pedicle valves), upper part of the Balogh's locality: 37 specimens (15, 5, 17), locality S-7: 1 specimen (0, 0, 1), loc. M-43: 2 specimens (0, 0, 2), M-46: 8 specimens (0, 0, 8), M-47: 2 specimens (0, 0, 2), loc. Šimák near the elevation point 419.3: 2 specimens (0, 0, 2), loc. A 1-77: 8 specimens (3, 1, 4), new trench - red nos.12-13: 5 specimens (0, 0, 5), nos.16-18: 22 specimens (0, 2, 20), nos.24-25: 1 specimen (0, 0, 1), Ostré vŕšky Hill-loc.B_2A: 202 specimens (173, 10, 19) and loc. O_2: 1 pedicle valve.

***Mentzelia halobiarum versata* ssp. n.**
(Pl. 1, Fig. 7, Pl.3, Figs. 1, 3-6, Text-Figs. 1-6, 9-10 B,C)

Holotype: Specimen figured on Pl. 3, Fig. 4 and deposited in the collections of the Slovak National Museum in Bratislava under registered number SNM Z 21986.

Stratum typicum et *locus typicus:* Greyish and flesh-coloured micrites, Tuvalian (*Subbulatus- ?Anatropites* Zones) Silická Brezová, upper part of Balogh ´s locality.

Derivatio nominis: Lat. versare, -atum = to reverse.

Material: 72 complete specimens up to 21.0 mm long, 18.0 mm wide and 16.5 mm thick, 17 brachial and 9 pedicle valves. The dimensions of the figured specimens: 9.3 x 10.0 x 6.0 mm (Pl. 1, Fig. 7), 10.6 x 10.2 x 7.8 mm (Pl. 3, Fig. 1), 16.5 x 16.0 x 13.5 mm (Pl. 3, Fig. 3), 16.4 x 16.2 x 10.9 mm (Pl. 3, Fig. 4 -holotype), 11.2 x 10.4 x 7.9 mm (Pl. 3, Fig. 5), 11.9 x 9.2 x 8.8 mm (Pl. 3, Fig. 6).

Internal characters: The sections could be misrepresen-

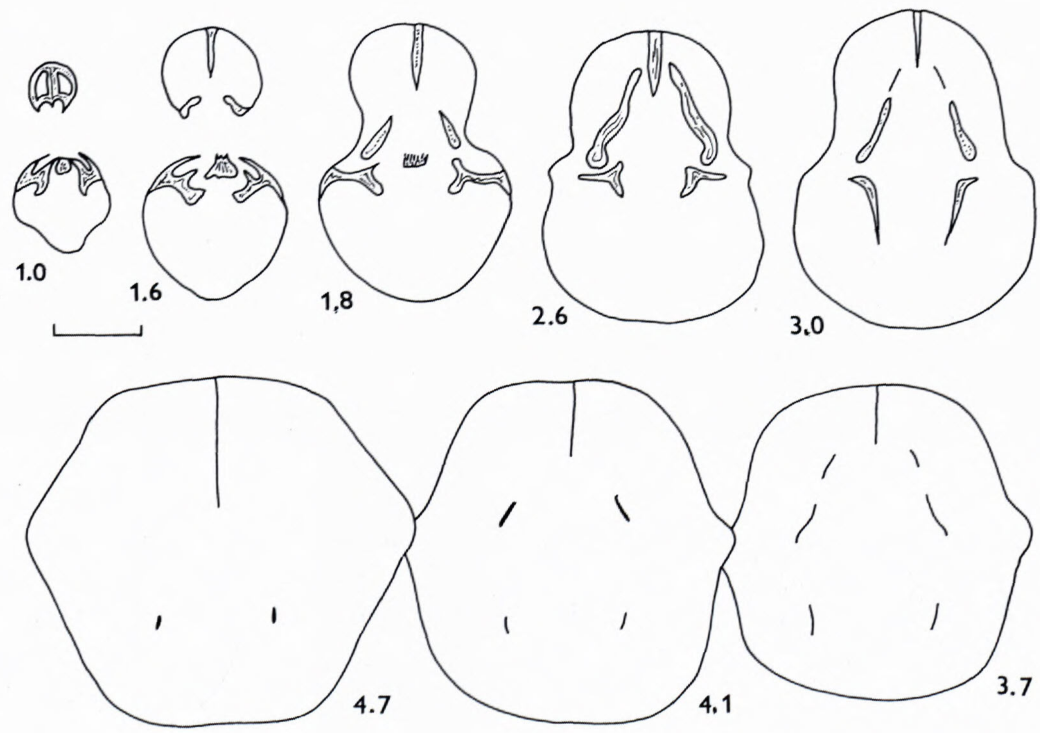


Fig. 9 *Mentzelia halobiarum versata* ssp.n. Silická Brezová, upper part of Balogh 's locality. Length of specimen = length of brachial valve 16.1 mm. Enlarged, scale bar equals 3 mm.

ted due to unusual, reverse position of valves. Sections are not substantially distinct from those of previously described *Mentzelia halobiarum halobiarum*. The spondylium-like structure is well developed, with median septum usually continuing into spondylial cavity (Figs. 10 C, D). The septum is longer in average than in *Mentzelia halobiarum halobiarum*, extending to more than 1/3 the length of pedicle valve. Poor preservation precluded further serial sectioning of studied specimens.

Definition and *remarks:* New subspecies was distinguished from *Mentzelia halobiarum halobiarum* by relatively narrower shells, very short hinge line, usually narrower and higher uniplication, much thicker brachial valve in comparison with pedicle valve, and specially by large, swollen dorsal beak incurved over hinge line. The reverse condition is best seen on shell profile: the beak of brachial valve overpasses that of pedicle one (extreme condition is perspicuous on specimen figured on Plate 4, Fig. 6). There may be up to 6 poorly developed ribs present on the lateral slopes of valves bordering the sulcus and fold of adult individuals of the new subspecies.

Occurrence: Silická Brezová - upper part of Balogh's locality: 88 specimens (64 complete specimens, 15 brachial and 9 pedicle valves), lower part of Balogh's locality: 7 specimens (7, 0, 0), loc. Šimák near the elevation point 419.3: 2 specimens (1, 1, 0), and locality A 1-77: 1 brachial valve.

Superfamily *Spiriferinoidea* DAVIDSON, 1884
Family *Spiriferinidae* DAVIDSON, 1884
Subfamily *Spiriferininae* DAVIDSON, 1884
Mentzelioides DAGYS, 1974

***Mentzelioides* (?) sp. n.**
(Pl.1, Fig. 3)

Material: One slightly deformed specimen with dimensions 19.5 x ?18.5 x 13.0 mm.

Remarks: A specimen externally similar to the Liassic spiriferinids ex gr. *alpina* OPPEL, 1861: medium sized, smooth impunctate (?) shell with length exceeding width, brachial valve less convex than the pedicle one, strong

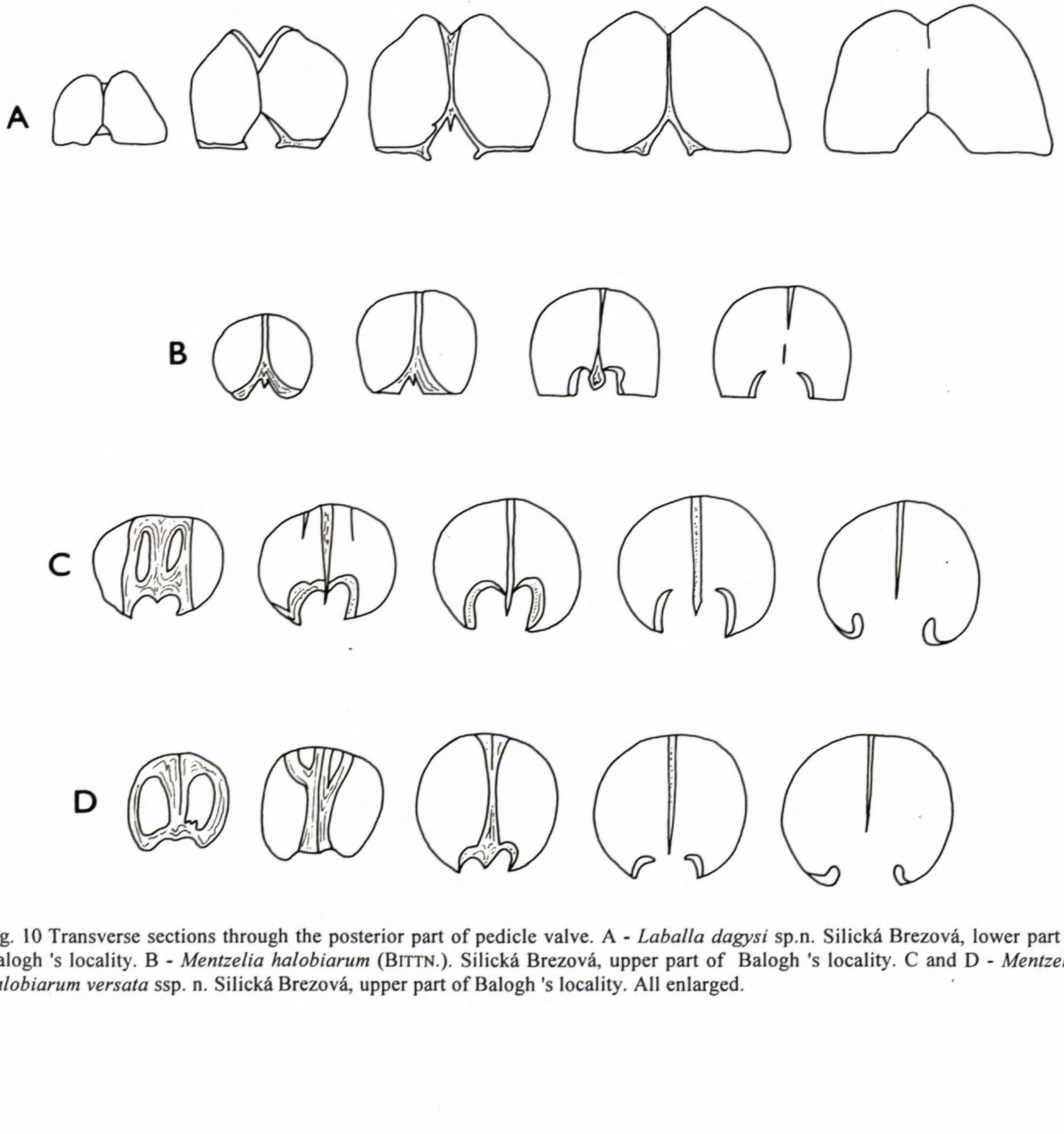


Fig. 10 Transverse sections through the posterior part of pedicle valve. A - *Laballa dagysi* sp.n. Silická Brezová, lower part of Balogh 's locality. B - *Mentzelia halobiarum* (BITTN.). Silická Brezová, upper part of Balogh 's locality. C and D - *Mentzelia halobiarum versata* ssp. n. Silická Brezová, upper part of Balogh 's locality. All enlarged.

relatively wide umbo present on the pedicle valve, straight hinge line sharply delimited on both sides, only slight uniplication anteriorly. Short dental lamellae ascertainable externally on the pedicle umbo.

As I do not find any parallel among Upper Triassic species, further comparisons are presently made difficult owing to the insufficient material.

Occurrence: Silická Brezová - lower part of Balogh 's locality.

Suborder *Cyrtinidina* CARTER & JOHNSON, 1994
uperfamily *Suessioidea* WAAGEN, 1883
Family *Laballidae* DAGYS, 1962
Subfamily *Laballinae* DAGYS, 1962
Laballa MOISSEIEV in DAGYS, 1962

***Laballa dagysi* sp. n.**
(Pl. 4, Figs. 1-4, 6, Text-Figs. 10 A, 11-20)

1940 *Cyrtina Suessii* WINKL. - BALOGH, p. 172, 195, Pl. 1, Fig. 1.
?1940 *Cyrtina ? ambigua* n. sp. - BALOGH, p. 173, 196, Pl. 1, Fig. 2.

Holotype: Specimen figured on Pl. 4, Fig. 3 and deposited in the collections of the Slovak National Museum in Bratislava under registered number SNM Z 21991.

Stratum typicum et *locus typicus:* Light-coloured coquina limestone, Tuvalian (*Subbulatus* Zone), Silická Brezová - lower part of Balogh's locality.

Derivatio nominis: After Prof. A. DAGYS (Vilnius), eminent specialist on Mesozoic brachiopods.

Material: 102 complete specimens, 58 brachial and 227 pedicle valves. Specimens have been seen up to 24.0 mm long, 30.0 mm wide and 16.0 mm thick. Figured specimens measure: ?17.3 x 18.7 x 10.9 mm (Pl. 4, Fig. 1), 10.6 x 14.5 x 8.6 mm (Pl. 4, Fig. 2), ca.18.0 x 22.2 x 13.0 (Pl. 4, Fig. 3 - holotype), 18.6 x 20.2 x 11.5 mm (Pl. 4, Fig. 4), and ? x 30.0 x ca.15.0 mm (Pl. 4, Fig. 6).

Description: Medium sized smooth spiriferid with the shell outline slightly wider than long; transversally elongated to semicircular brachial valve shallow, pedicle one subpyramidal with a pointed beak, only minimally recurved at the apex (Pl. 4, Fig. 4). Hinge line slightly shorter than maximum width. Interarea catacline, large, triangular and flat, wider than high, sharply delimited by angular ridges; in young specimens may be either procline.Sulcus and fold large, strongly developed and well delimited. Linguiform plication of the anterior commissure high and rounded.

Internal characters: Only a few specimens in my large collection appeared to be suitably preserved for sectioning. Variable length of the pedicle septum is characteristic of them. The transverse sections show the essential features of *Laballa* as they were described or figured in the type species *Laballa suessi* by DAGYS (1963, p. 88, Figs. 39-40 or 1965, Fig. 42), PEARSON (1977, p. 21, Fig. 2), and in this paper (Text-Fig. 21). Sections of my specimens are very similar to those obtained from the mentioned Alpine specimens of "*suessi*". A satisfactory reconstruction of jugum and spiralia is still missing, however.

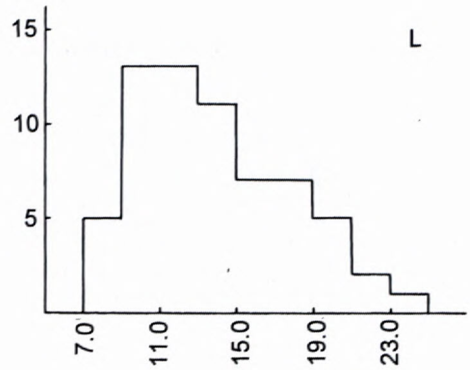


Fig. 11 Length frequency histogram for 64 complete specimens of *Laballa dagysi* sp.n., in mm. Vertically number of specimens.Silická Brezová, lower part of Balogh 's locality.

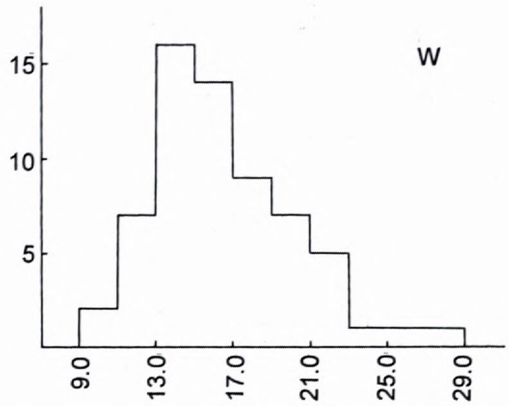


Fig. 12 Width frequency histogram (for explanation see Fig.11).

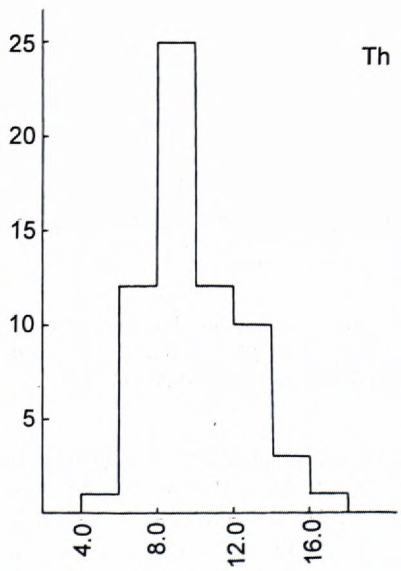


Fig. 13 Thickness frequency histogram (for explanation see Fig.11).

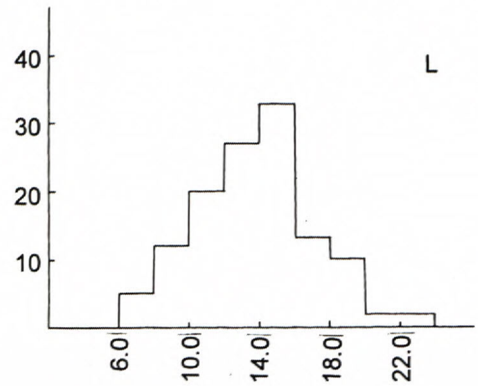


Fig. 14 Length frequency histogram for 134 isolated pedicle valves of *Laballa dagysi* sp.n., in mm. Vertically number of specimens. Silická Brezová, lower part of Balogh 's locality.

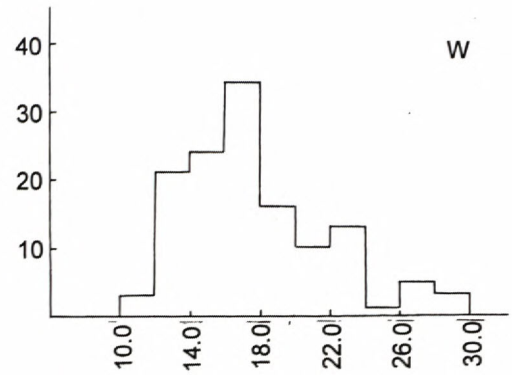


Fig. 15 Width frequency histogram (for explanation see Fig.14).

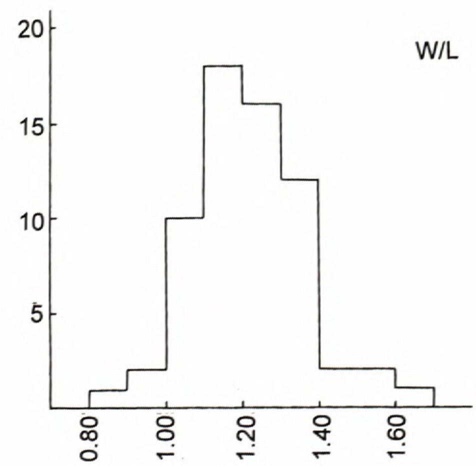


Fig. 16 Width/length frequency histogram for 64 complete specimens of *Laballa dagysi* sp.n., in mm. Vertically number of specimens. Silická Brezová, lower part of Balogh 's locality.

Remarks:.The new species shows considerable similarity to Rhaetian *Laballa suessi* (ZUGM.), and despite the great age difference between the Carnian and Rhaetian, the specimens from the Carnian of the Slovak Karst have been a long time identified as *"suessi"* (for example by BALOGH, 1940, BYSTRICKÝ, 1964, SIBLÍK, 1986, 1997). Also PEARSON 's (1977, p. 22) presumption was that the separation of material from Silická Brezová from ZUGMAYER's *"suessi"* is not practicable. Great external variability of both species may lead to single specimens which are impossible to be easily distinguished. In the case that larger material is available, the average characteristics make the differentiation of the two species possible. *Laballa dagysi* sp. n. may be distinguished from *Laballa suessi* (ZUGM.) by a relatively longer hinge line, narrower delthyrium, higher, rounded linguiform extension rising sharply from the anterior commissure, and a slight apical recurving of the pedicle valve. Ledges bordering the delthyrium in *"suessi"* are only poorly developed in *"dagysi"*. Certain irregularities in the shell symmetry are characteristic of the new species, and are caused most probably by the nature of the former substrate. A great age difference between the two species is also an important factor.

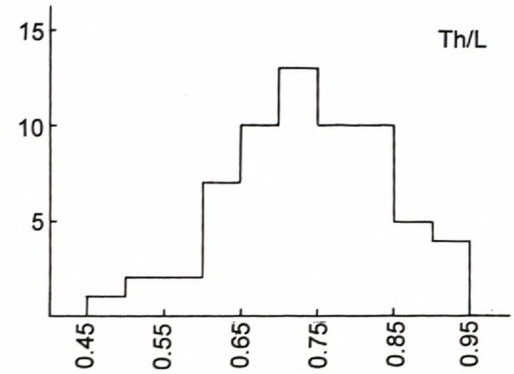


Fig.17 Thickness/length frequency histogram (for explanation see Fig.16).

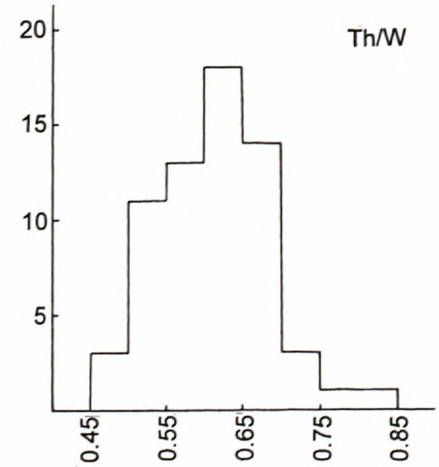


Fig.18 Thickness/width frequency histogram (for explanation see Fig.16).

A new species *Cyrtina* ? *ambigua* based on 2 specimens (1 type specimen and 1 fragment), was described from Silická Brezová by Balogh in 1940. Judging from Balogh´s illustration, there was every reason to believe in the apsacline character of area in the type specimen and it was at the same time the main difference from *"suessi"* (with its catacline area). However, my personal study of

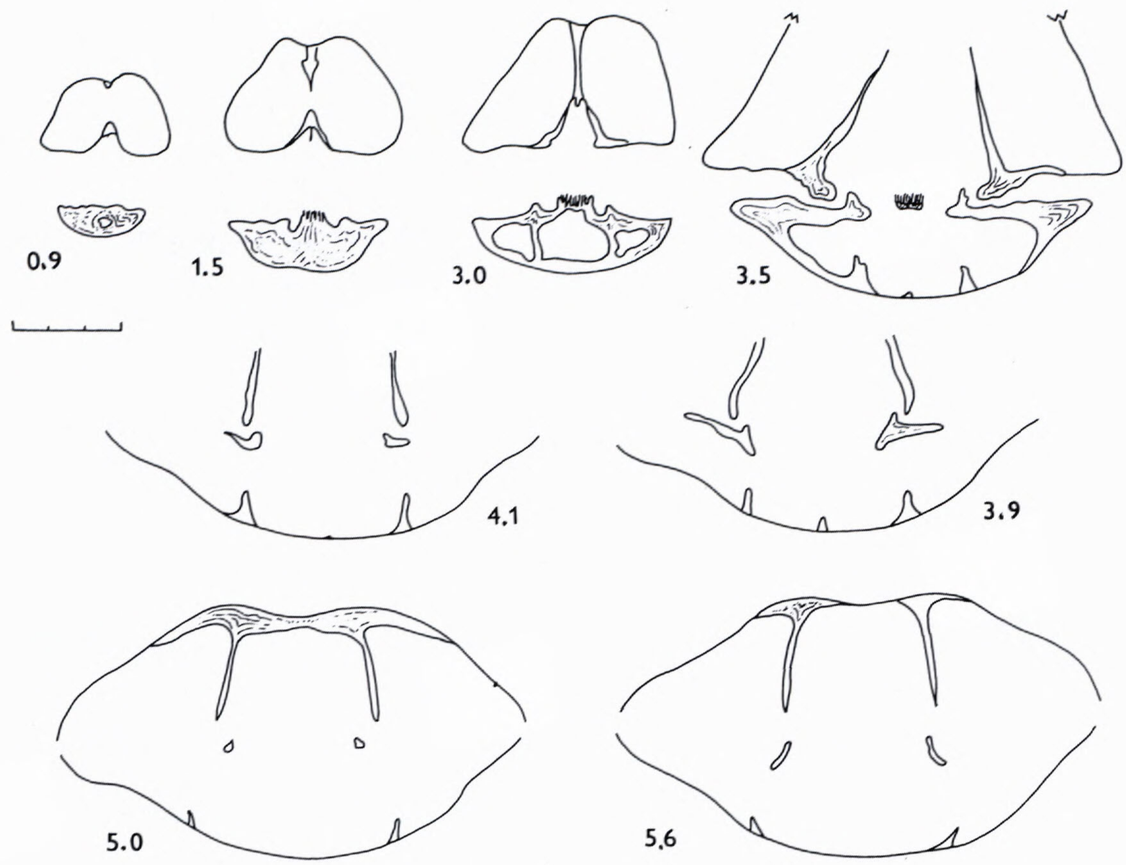


Fig. 19 *Laballa dagysi* sp.n. Original length 19.0 mm. Silická Brezová, lower part of Balogh 's locality. Enlarged, scale bar equals 3 mm.

Balogh´s collection deposited in the Geological Survey in Budapest formerly showed that reported orientation of pedicle valve is illusory. Balogh´s type specimen of *"ambigua"* is strongly damaged in the terminal part of its pedicle valve whereas the lower part of area clearly reveals a catacline orientation, usual in *"suessi"*. In my and Bystrický' s large, very variable material from the Slovak Karst, there have not been found additional specimens similar to Balogh´s *"ambigua"*. For reasons of stability, this name is not used for material from Silická Brezová. It is even not certain if Balogh´s specimen of *"ambigua"* is a deformed, fragmentary variant of *Laballa* because its internal structures are not known. In addition, Balogh was not quite sure about generic identity, having described the

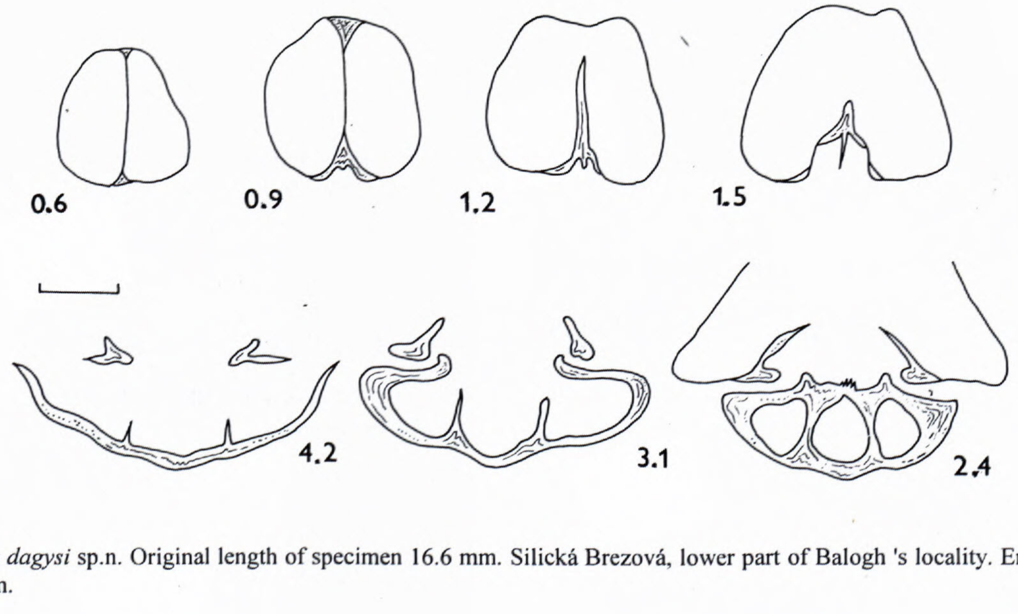


Fig. 20 *Laballa dagysi* sp.n. Original length of specimen 16.6 mm. Silická Brezová, lower part of Balogh 's locality. Enlarged, scale bar equals 3 mm.

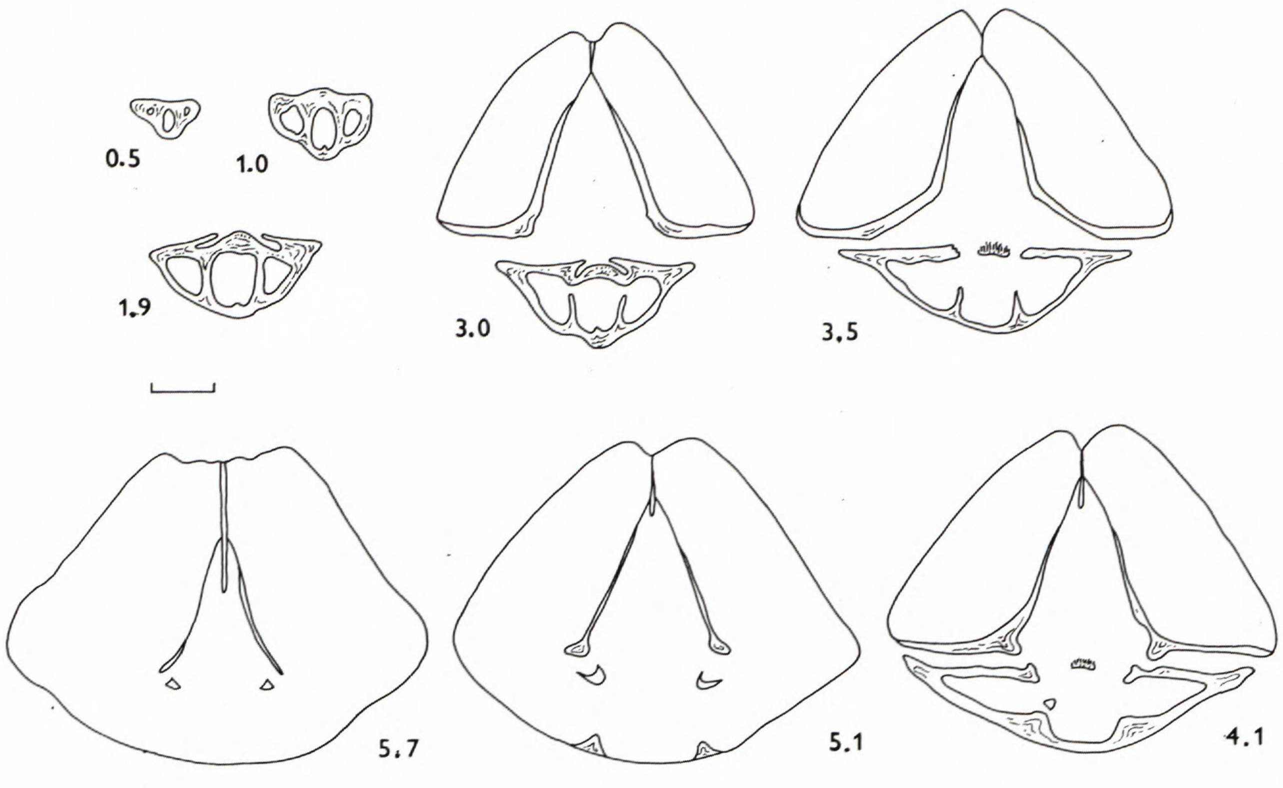


Fig. 21 *Laballa suessi* (ZUGM.). Original length of specimen ca. 30.0 mm. Kössen Beds, Kitzberg by Neusiedl, Lower Austria (coll. Palaeont.Inst.Univ.Vienna). Enlarged, scale bar equals 5 mm.

species as *Cyrtina*? Moreover, during my visit to Budapest in 1996, the original specimen could not be traced. *Cyrtina* ? *ambigua* is placed here then with doubts into synonymy with *Laballa dagysi* sp.n.

Occurrence: Silická Brezová - lower part of Balogh´s locality: 299 specimens (86 complete specimens, 38 brachial and 175 pedicle valves), upper part of Balogh´s locality: 4 specimens (1, 0, 3), Šimák near the elevation point 492.2: 13 specimens (1, 2 10), loc. A 1-77: 1 specimen (1, 0, 0), loc. M-46: 3 specimens (2, 1, 0), loc.M-47: 2 specimens (2, 0, 0), loc. M-48, 49: 2 specimens (0, 2, 0), 60 m ESE of M-49: 9 specimens (0, 4, 5), new trench - red nos.16-18: 10 specimens (5, 2, 3), Ostré vŕšky Hill -loc. B_2A: 35 specimens (3, 6, 26), locality "Gemerské lúky" N of Ostré vŕšky Hill: 3 specimens (0, 1, 2).

Subfamily *Thecocyrtellinae* DAGYS, 1965
Thecocyrtella BITTNER, 1892

Thecocyrtella ampezzana (BITTNER, 1892)
(Pl.1, Fig.10)

1890 *Cyrtotheca Ampezzana* nov.gen.nov.spec. - BITTNER, p.116, Pl.38, Fig.19.
1900 *Thecocyrtella Ampezzoana* BITT. - BITTNER, p. 26, Pl. 3, Fig. 24.
1918 *Thecocyrtella ampezzoana* BITT. - GALLENSTEIN, p. 53.
1920 *Thecocyrtella Ampezzana* BITTNER - DIENER, p. 59.
1930 *Thecocyrtella Ampezzoana* BITTNER - GUGENBERGER, p. 72.
1974 *Thecocyrtella ampezzana* (BITTNER) - DAGYS, p. 149.
1988 *Thecocyrtella ampezzana* (BITTNER) - SIBLÍK, p. 74.

Holotype by monotypy: the specimen lost (see BITTNER, 1890).
Locus typicus: Falzarego road, W of Cortina d'Ampezzo.
Stratum typicum: ? Carnian.
Material: One specimen with dimensions 5.3 x 3.7 x 4.0 mm.
Remarks: A diminutive specimen corresponds well to the Bittner 's original figure and detailed description of the type specimen, and shows the only difference - a pointed beak of brachial valve only slightly recurved apically. It is the first find of this "southern" element in the West Carpathians.
Occurrence: Silická Brezová - lower part of Balogh 's locality.

Order *Athyridida* BOUCOT, JOHSON & STATON, 1964
Suborder *Athyrididina* BOUCOT, JOHSON & STATON 1964
Superfamily *Athyridoidea* DAVIDSON, 1881
Family *Spirigerellidae* GRUNT, 1965
Subfamily *Spirigerellinae* GRUNT, 1965

Dioristella BITTNER, 1890

Dioristella indistincta (BEYRICH, 1863)
(Pl. 1, Figs. 8-9)

1863 *Terebratula indistincta* BEYRICH, p. 34.
1866 *Terebratula indistincta* BEYRICH - LAUBE, p. 6, Pl. 11, Figs. 4-6 only.
1890 *Spirigera indistincta* BEYR. spec. - BITTNER, p. 59, 86, 147, 164, Pl. 29, Figs. 28-31.

1900 *Spirigera (Dioristella) indistincta* BEYR. spec. - BITNER, P. 32, pl. 3, Figs. 1-6.
1904 *Spirigera indistincta* BEYR. sp. - WAAGEN, p. 450.
1904 *Spirigera indistincta* BEYR. - BROILI, p. 159, Pl. 18, Fig. 1.
1910 *Spirigera (Dioristella) indistincta* BEYR. sp. - SCALIA, p. 19, Pl. 2, Figs. 2-7.
1927 *Spirigera indistincta* BEYRICH - OGILVIE-GORDON, Pl. 12, Fig. 3l.
1974 *Dioristella indistincta* (BEYRICH, 1862) - DAGYS, p.155, Text-Fig.104, Pl. 43, Fig. 3.
1975 *Dioristella indistincta* (BEYRICH, 1862) - BUJNOVSKÝ KOCHANOVÁ & PEVNÝ, p. 39, Pl.3, Figs. 2-3, Pl. 4, Fig. 1.
1988 *Dioristella indistincta* (BEYRICH) - SIBLÍK, p. 77 (cum syn.).

Lectotype: not selected.
Locus typicus: Füssen, Bavaria.
Stratum typicum: Carnian (according to DIENER, 1920, p. 65).
Material: 95 specimens up to 7.8 mm in length, 6.0 mm in width and 5.5 mm in thickness. The figured specimens measure: 7.7 x 6.0 x 4.8 mm (Pl.1, Fig. 8) and 7.5 x 5.7 x 5.0 mm (Pl.1, Fig. 9).
Remarks: Our specimens are characterized by ovate to pear-shaped outline and variable thickness, most of them are slightly uniplicate. Three specimens develop high, incurved lateral and anterior flanges (similar to those of specimen figured by Bittner, 1890 on Pl. 29, Fig. 3l). The interiors show nearly complete recrystallization, but simple spiralia are ascertainable.
Occurrence: Carnian. One specimen comes from the Ostré vŕšky Hill (loc. B_2A), the others were collected formerly by Bystrický near the Ostré vŕšky Hill ("Gemerské lúky, above *Teutloporella* limestone"). Other localities: Liptovská Osada and Ludrová near Ružomberok, Predhorie in the Strážovská hornatina Mts. (Pevný in Bujnovský, Kochanová & Pevný, 1975), Dudlavá skala in the Horehronské podolie valley (Biely & Papšová, 1983). Some similarities to the species under consideration were found in the material coming from Jablonov in the Slovak Karst (Wetterstein Limestone) and were described as *Dioristella* aff. *indistincta* by Siblík (1981)

Suborder *Retziidina* BOUCOT, JOHNSON & STATON, 1964
Superfamily *Retzioidea* WAAGEN, 1883
Family *Neoretziidae* DAGYS, 1972
Subfamily *Hustediinae* GRUNT, 1985
Schwagerispira DAGYS, 1972

Schwagerispira bystrickyi SIBLÍK, 1990

1990 *Schwagerispira bystrickyi* sp.n. - SIBLÍK, p.104, Pl. 42, Figs. 1-3, Pl. 43, Fig. 1, Text-Figs. 1-2.

Holotype: Figured by Siblík, 1990 on Pl. 42, Fig. 2. It is deposited in the collections of the Slovak National Museum (no. SNM Z 20023).
Locus typicus: Silická Brezová, upper part of Balog's locality.
Stratum typicum: Tuvalian, *Subbulatus* and *Anatropites* (?) Zones.
Material: 42 specimens. The holotype measures 10.4 x 8.6 x 8.0 mm.
Remarks: Nothing is to be added to the description given in 1990. The species has been found at additional localities, it belongs to the relatively rare finds, however.
Occurrence: Silická Brezová - lower and upper parts of Balogh 's locality, locality K-2, loc. M-46 and 47, loc. 60 m ESE of M-49l, and bed 16 (red numbers) of the new trench.

Complete list of Carnian brachiopods found in the Slovak Karst

Former Balogh's locality I. (1940) SW of the village of Silická Brezová is the best locality for the Carnian brachiopod fauna of the Slovak Karst. There has been possible to distinguish 2 levels with different brachiopod assemblages (Siblík, 1986). The lower part is represented by the light-coloured coquina "Tisovec" Limestone that corresponds to the Tuvalian *Subbulatus* Zone; the upper part is flesh-coloured or greyish micrite limestone that probably corresponds to the Uppermost Tuvalian *Anatropites* Zone (see Kochanová & Kollárová-Andrusovová, 1983, p. 554-555). There may be both stratigraphical and environmental significance in this variation of brachiopod content. According to the brachiopod assemblages , most of the other Carnian localities on the Silica and Plešivec Plateaus are considered here to be more or less contemporaneous with the lower part of Balogh 's locality. Only a few localities near Silická Brezová are compared to the upper part of BALOGH's locality, as they contain corresponding "upper" brachiopod assemblages (locality A 1-77, M-42 and beds of red nos.24-25 in the new trench).

Taxa found in the lower assemblage:
Austriellula gomorensis (BAL.)
Rimirhynchopsis aff. *rimulata* (BITTN.)
Volirhynchia dux SIBL.
Caucasorhynchia elegans elegans SIBL.
Gemerithyris hungarica hungarica (BAL.)
Aulacothyris compressa BITTN.
Aulacothyris sinuosa BAL.
Rhaetina concinna SIBL.
Koninckina cf. *alata* BITTN.
Koninckina cf. *strophomenoides* BITTN.
Mentzelioides (?) sp. n.
Thecocyrtella ampezzana (BITTN.)
Ostré vŕšky only:
Austriellula angulifrons (BITTN.)
Austriellula halophila (BITTN.)
Caucasorhynchia elegans consobrina SIBL..
Aulacothyris sandlingensis BITTN.
Cruratula (?) sp.
Propygope (?) sp.
Dioristella indistincta (BEYR.)

Taxa found in the upper assemblage:
Norella obesa SIBL.
Apertirhynchella triplex SIBL.
Amoenirhynchia seydeli (BITTN.)
Costirhynchopsis variata glabra SIBL.

Gemerithyris copiosa inflata SIBL.
Gemerithyris hungarica globosa SIBL.
Austriellula undosa SIBL. (also Ostré vŕšky Hill)
Pseudorugitella pulchella (BITTN.) (also Ostré vŕšky Hill)

Taxa found both in the lower and upper assemblages:

Costirhynchopsis variata variata SIBL.
Gemerithyris copiosa copiosa SIBL.
Sulcatothyris rotunda SIBL.
Carinokoninckina telleri (BITTN.)
Carinokoninckina aff.*expansa* (BITTN.)
Mentzelia halobiarum halobiarum (BITTN.)
Mentzelia halobiarum versata ssp. n.
Laballa dagysi sp. n.
Schwagerispira bystrickyi SIBL.

References

Balogh, K., 1940: Daten zur geologischen Kenntnis der Umgebung von Pelsöcardó. Abh. miner.-geol. Inst. St. Tisza - Univ. (Debrecen), 19, 151-200.

Beyrich E., 1863: Über das Vorkommen von St. Cassianer Versteinerungen bei Füssen, aus dem Jahre 1862. Monatsber. kön. Preuss. Akad. Wiss. (Berlin), 27-40.

Biely J. & Papšová J., 1983: Upper Triassic limestones from Dudlavá skala (Horehronské podolie valley). Geol. práce, Spr. (Bratislava), 79, 267-272 (in Slovak, Engl.rés.).

Bittner A., 1886: Über das Vorkommen von Koninckiniden und verwandten Brachiopodengattungen im Lias der Ostalpen und in der alpinen Trias. Verh.k.k.geol.Reichsanst.(Wien), 52-56.

Bittner A., 1890: Brachiopoden der alpinen Trias. Abh. k. k. geol. Reichsanst. (Wien), 14, 1-320.

Bittner A., 1900: Brachiopoden aus der Trias des Bakonyerwaldes. Result. wiss. Erforsch. Balatonsees (Budapest), 1, 1, 1-59.

Broili F., 1904: Die Fauna der Pachycardientuffe der Seisser Alp. Palaeontographica (Stuttgart), 50, 145-227.

Bujnovský A., Kochanová M. & Pevný J., 1975: Korytnica Limestones - a new stratigraphical unit and its fauna. Geol. práce, Spr. (Bratislava), 63, 21-53.

Bystrický J., 1964: Stratigraphie und Dasycladaceen des Gebirges Slovenský Kras. Bratislava, ÚÚG, 197 p. (in Slovak, Germ.rés.).

Bystrický J., Jendrejáková O. & Papšová J., 1982: Contribution to the stratigraphy of the Triassic in the Stratenská hornatina Mts. Mineralia slov. (Bratislava), 14, 289-321 (in Slovak, Engl.rés.).

Dagys A. S., 1963: Upper Triassic brachiopods of the Southern USSR. Moscow, Acad. Publ. House, 238 p.(in Russian).

Dagys A. S.,1965: Triassic brachiopods of Siberia. Moscow, Acad.Sci USSR, Siber. branch, Inst. Geol. Geoph., 186 p. (in Russian).

Dagys A. S.,1974: Triassic brachiopods (morphology, classification, phylogeny, stratigraphical significance and biogeography).- Trans. Inst. Geol. Geoph. Acad. Sci. (Novosibirsk), Nauka, 214, 322 p.(in Russian).

Dagys A., 1996: On the classification of the order Athyridida. In Copper P. & Jin J.(eds.): Brachiopods. Proceed. 3. int. Brach. Congr. Sudbury. Rotterdam/Brookfield, Balkema A. A., 89-90.

Diener K., 192O: Brachiopoda triadica. Fossilium Catalogus, I, Animalia, 10 (Berlin), 108 p.

Entcheva M. : Les fossiles de Bulgarie. 2. Le Trias (Sofia), Acad. Bulg. Sc., 152 p. (in Bulg.).

Gallenstein H. von, 1918: Ein neuer Fund von Foraminiferen und die Brachiopoden Thecospirella Loczyi BITTN. und Thecocyrtella ampezzoana BITTN.in den Cardita-Schichten Mittelkärntens. Carinthia II (Klagenfurt), 28, 50-53.

Gugenberger O., 1930: Die Cardita-Schichten von Launsdorf in Mittelkärnten und ihre Fauna. I. Brachiopoden. Sitz.-Ber. Akad. Wiss., math.-naturwiss. Kl. (Wien), 1. 139, 43-130.

Gyalog L., Detre Cs. & Csillag G., 1993: Upper Triassic brachiopodal dolomite in the Gánt region.- Ann. Rep. Hung .Geol. Surv. (1991), (Budapest), 2, 175-187.

Jin Y.K. & Fang B. X., 1977: Upper Triassic brachiopod fauna from the area in the east of the Hengduan Mountains, Western Yunnan. Mesozoic Fossils from Yunnan, China (Peking), 2, 39-66 (in Chinese).

Kochanová M., 1987: Obertriassische Muscheln von Ostré vŕšky (Slowakische Karst). Záp. Karp., Pleont. (Bratislava), 12, 31–46.

Kochanová,. M. & Kollárová-Andrusovová V., 1983: Obetriassische Bilvalven und Ammonoiden der westlichen Umgebung von Silická Brezová (Slowakischer Karst, Westkarpaten). Geol. Zbor. (Bratislava), 34, 535–590.

Laube G.C., 1866: Die Fauna der Schichten von St. Cassian. 2. Brachiopoden und Bivalven. Denkschr.k.Akad.Wiss., math.-naturwiss. Kl. (Wien), 25, 1-76.

Ogilvie-Gordon M., 1927: Das Grödener-, Fassa- und Enneberggebiet in den Südtiroler Dolomiten.3.Paläontologie. Abhandl. geol. Bundesanst. (Wien), 24, I, 1-376, II. 1-89.

Pearson D.A.B.,1977: Rhaetian Brachiopods of Europe. N. Denkschr. Naturhist. Mus. (Wien), 1, 1-70.

Acalia S.,1910: La fauna del Trias superiore del Gruppo di Monte Judica. Mem.Acad.Gioenia sci.nat.(Catania), 5, 3, 1-51.

Siblík M.,1981: Brachiopods from the Wetterstein Limestone of the Horný vrch Karst Plateau (SE Slovakia). Záp.Karp., Paleont. (Bratislava), 6, 15-24.

Siblík M., 1986: Carnian rhynchonellid brachiopods from the Slovak Karst area. Záp. Karp., Paleont. (Bratislava), 11, 7-34.

Siblík M., 1988: Brachiopoda mesozoica, a)Brachiopoda triadica. Catalogus fossilium Austriae (Wien), Österr. Akad. Wiss., Heft Vc 2 (a), 124 p.

Siblík M., 1990: New Schwagerispira (Brachiopoda) from the Carnian of the Slovak Karst (SE Slovakia). Záp. Karp., Paleont.(Bratislava), 14, 103-108.

Siblík M., 1997: Carnian spiriferid brachiopods of the Slovak Karst. Zprávy o geol. výzk. 1996 (ČGÚ Praha), 75 (in Czech).

Siblík M., 1998: A contribution to the brachiopod fauna of the "Oberrhätkalk" (Northern Calcareous Alps). Jahrb. geol. Bundesanst. (Wien) (in print).

Toula Fr., 1913: Die Kalke vom Jägerhause unweit Baden (Rauchstallbrunnengraben) mit nordalpiner St.Cassianer Fauna. Jahrb. k. k. geol. Reichsanst. (Wien), 63, 77-126.

Waagen L., 1904: Brachiopoden aus den Pachycardientuffen der Seisser Alpen. Jahrb. k. k.geol. Reichsanst. (Wien), 53, 443-452.

Zugmayer H., 1880: Untersuchungen über rhätische Brachiopoden. Beitr. Paläont. Geol. Österr.-Ung. (Wien), 1, 1-42.

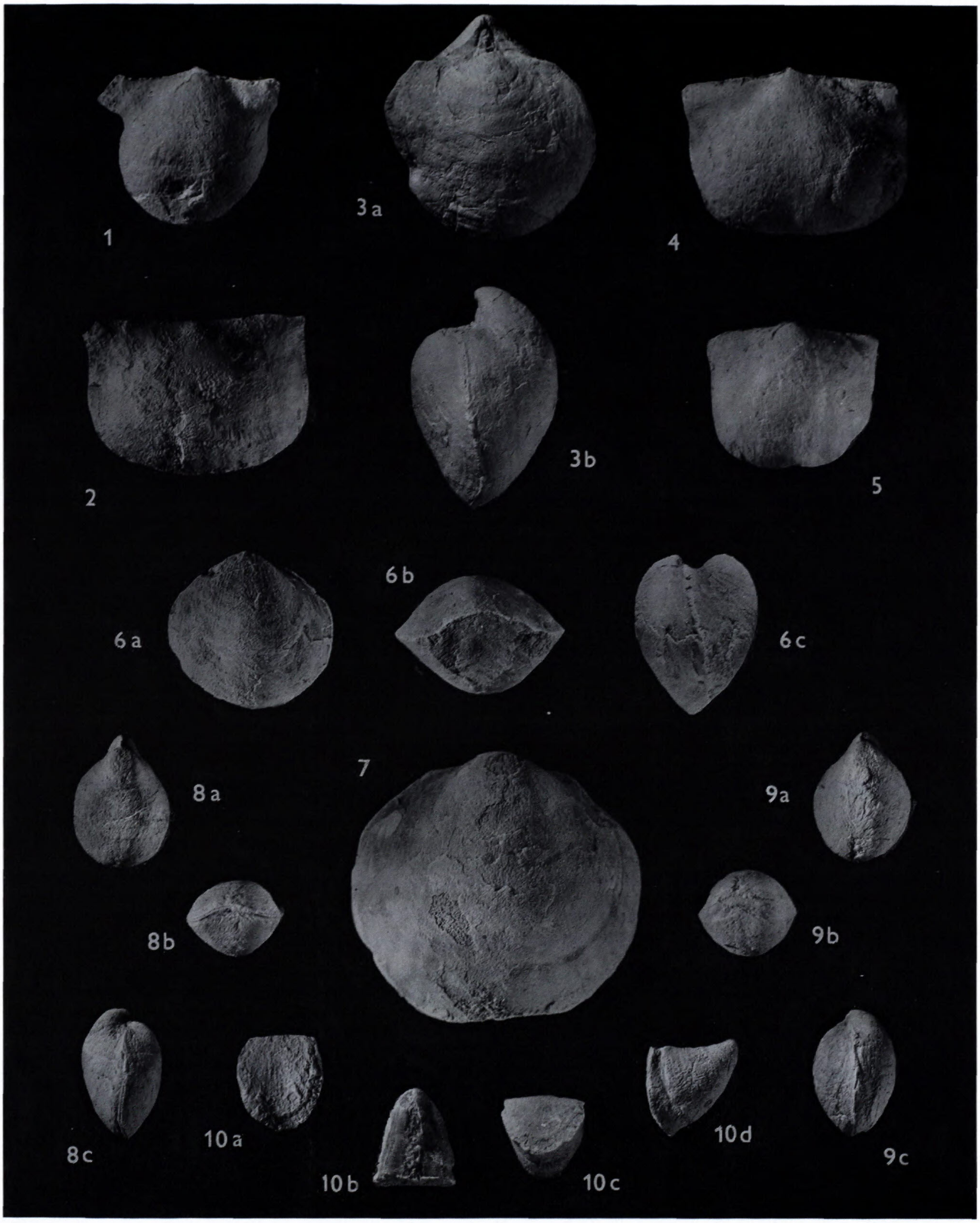


Plate 1

Fig. 1 *Koninckina* cf. *alata* BITTNER; Silická Brezová, lower part of Balogh 's locality, SNM Z 21971 (x 3); **Fig. 2** *Carinokoninckina* aff. *expansa* (BITTNER); Silická Brezová, lower part of Balogh 's locality, SNM Z 21972 (x 3); **Fig. 3** *Mentzelioides* sp. n.; Silická Brezová, lower part of Balogh 's locality, SNM Z 21973 (x 2); **Fig. 4** *Carinokoninckina telleri* (BITTNER); Silická Brezová, loc. Šimák near the elevation point 419.3. Coll. by Bystrický SNM Z 21974 (x 3); **Fig. 5** *Karinokoninckina telleri* (BITTNER); Silická Brezová, lower part of Balogh 's locality, SNM Z 21975 (x 3); **Fig. 6** *Mentzelia halobiarum* (BITTNER) - young specimen Ostré vŕšky Hill, loc. B_2A SNM Z 21976 (x 3); **Fig. 7** *Mentzelia halobiarum versata* ssp.n. -juvenile specimen; Silická Brezová, upper part of Balogh 's locality, SNM Z 21977 (x 5); **Figs. 8-9** *Dioristella indistincta* (BEYRICH) N of Ostré vŕšky Hill. Collected by Bystrický, SNM Z 21978-9 (x 3); **Fig. 10** *Thecocyrtella ampezzana* (BITTNER); Silická Brezová, lower part of Balogh 's locality, SNM Z 21980 (x 4)

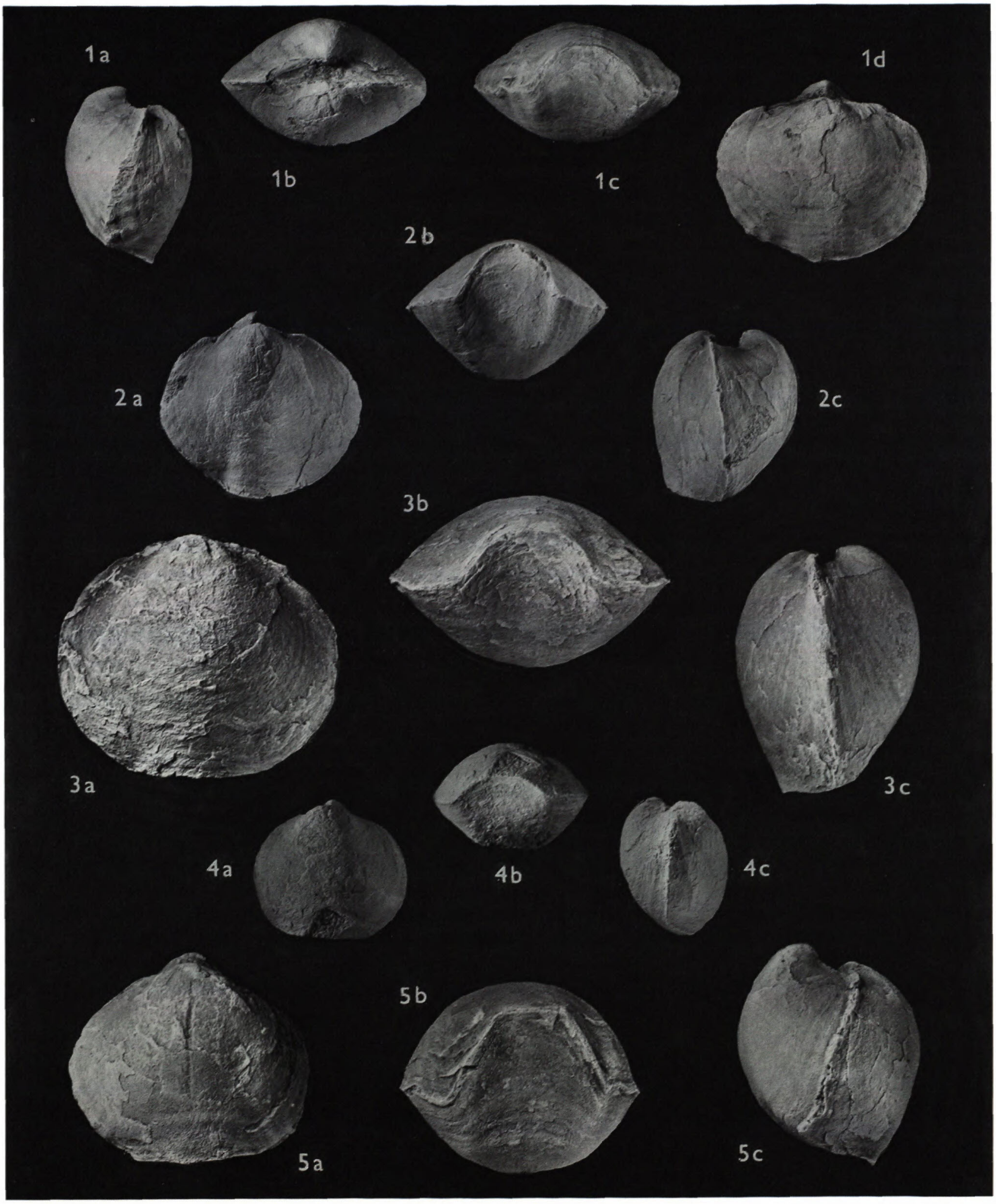


Plate 2

Fig. 1 *Mentzelia halobiarum* (BITTNER); Lectotype. Locality Bergstein near Landl a.d. Enns, Styria. Carnian. Collections of the Geologische Bundesanstalt in Vienna, inv. no. 1890/2/329 (x 2); **Fig. 2** *Mentzelia halobiarum* (BITTNER); Locality as Fig.1. Collections of the Geologische Bundesanstalt in Vienna. Specimen figured by Bittner, 1890 on Pl.14, Fig. 13 (x 2); **Fig. 3** *Mentzelia halobiarum* (BITTNER); Both terminations of the hinge line broken. Ostré vŕšky Hill, loc. B_2A, SNM Z 21981 (x 3); **Fig. 4** *Mentzelia halobiarum* (BITTNER); Ostré vŕšky Hill, loc. B_2A SNM Z 21982 (x 2); **Fig. 5** *Mentzelia halobiarum* (BITTNER); Balbersteine/Miesenbach, Lower Austria. Lowermost Norian. Collections of the Palaeontological Institute of the University Vienna (coll. Gruber) (x 3)

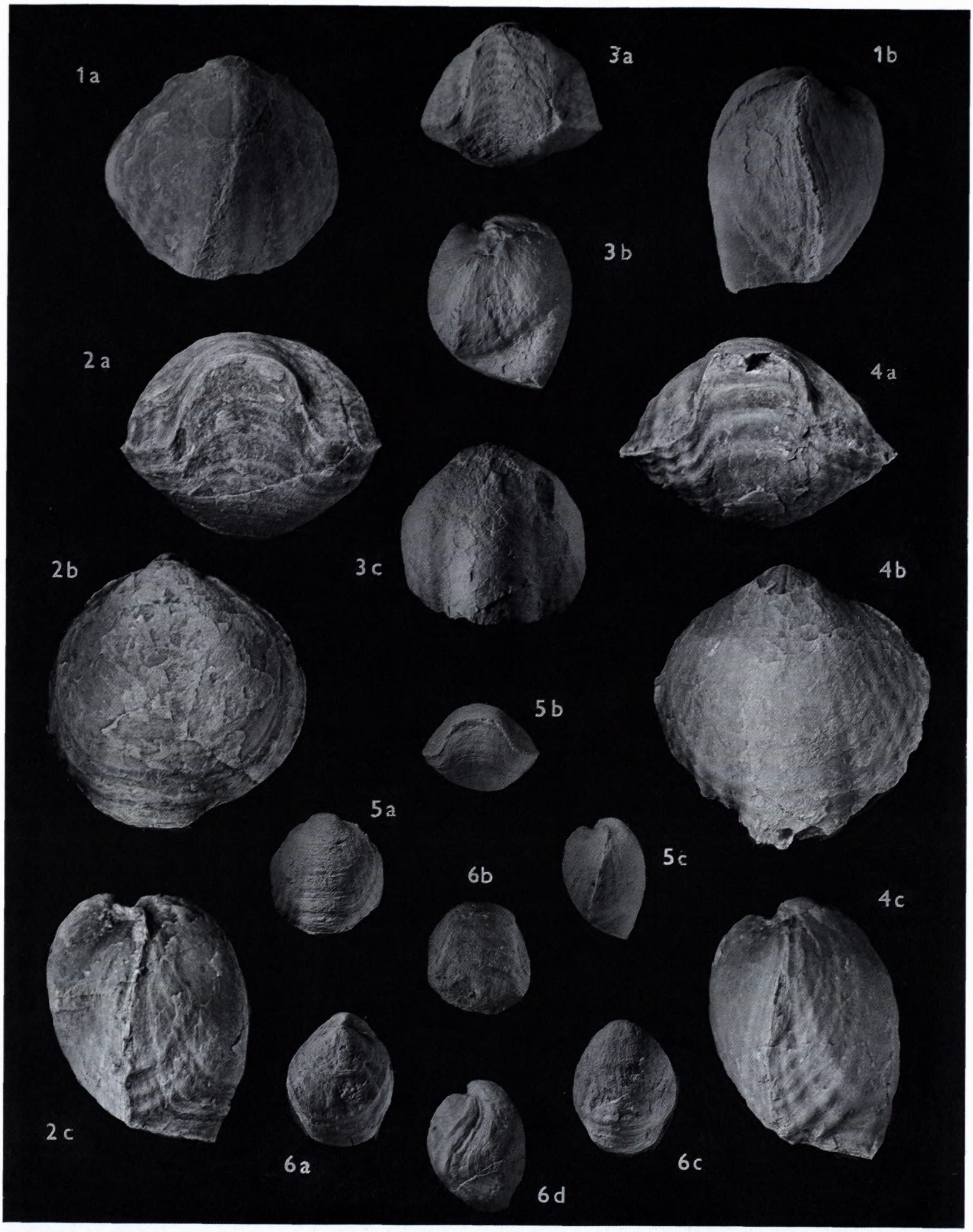


Plate 3

Fig. 1 *Mentzelia halobiarum versata* ssp. n.; Silická Brezová, upper part of Balogh 's locality, SNM Z 21983 (x 4); **Fig. 2** *Mentzelia halobiarum* (BITTNER), Ostré vŕšky Hill, loc. B_2A, SNM Z 21984 (x 3); **Fig. 3** *Mentzelia halobiarum versata* ssp. n.; Silická Brezová, upper part of Balogh 's locality, SNM Z 21985 (x 2); **Fig. 4** *Mentzelia halobiarum versata* ssp. n. Holotype. Silická Brezová, upper part of Balogh 's locality, SNM Z 21986 (x 3); **Fig. 5** *Mentzelia halobiarum versata* ssp.n.; Silická Brezová, upper part of Balogh 's locality, SNM Z 21987 (x 2); **Fig. 6** *Mentzelia halobiarum versata* ssp. n.; Silická Brezová, upper part of Balogh 's locality. Variant with extreme reversal of valves. 6a-ventral view, 6b-anterior view, 6c-dorsal view, 6d-lateral view with pedicle valve left, SNM Z 21988 (x 2)

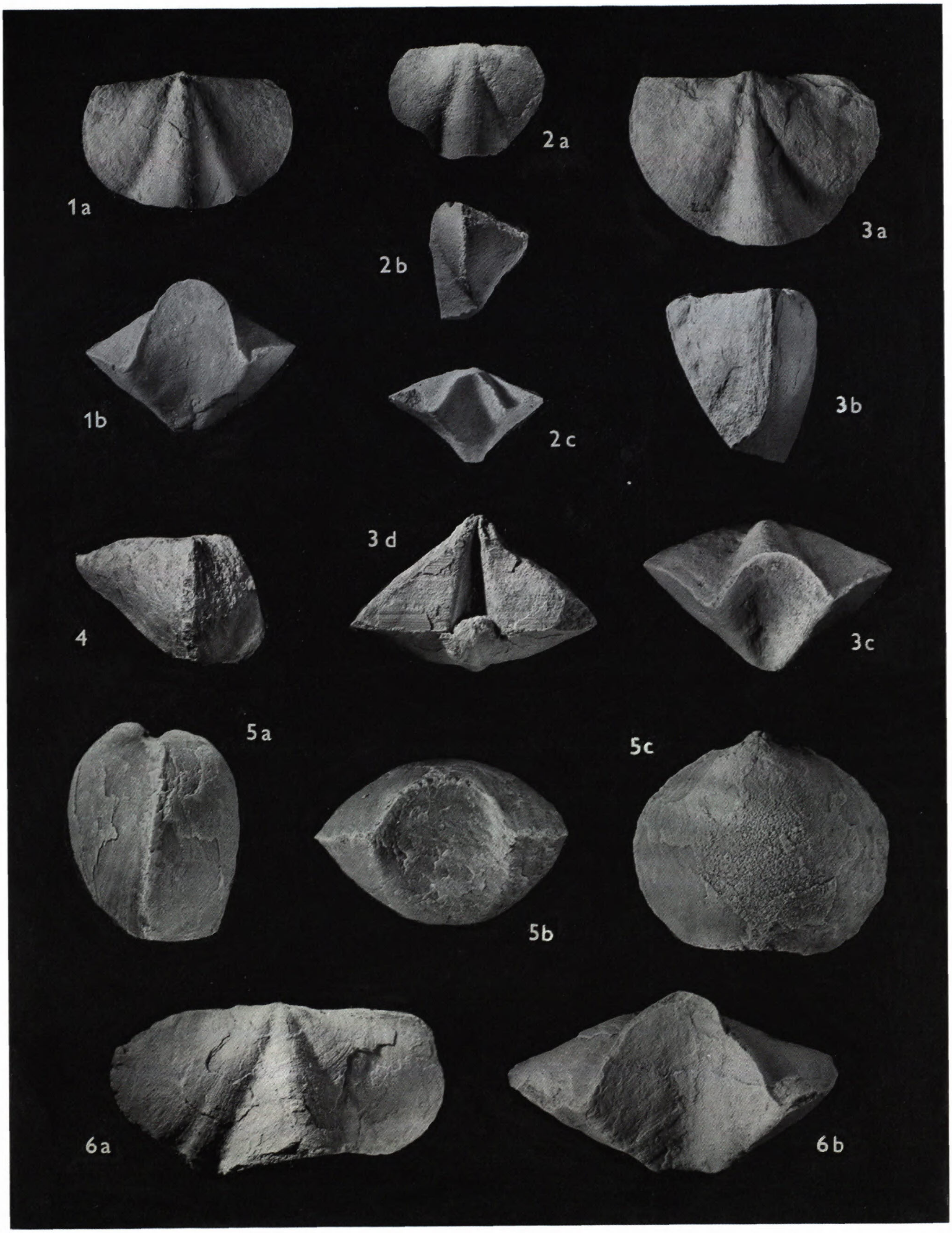


Plate 4

Figs. 1-4 *Laballa dagysi* sp. n.; Silická Brezová, lower part of Balogh 's locality. Specimen on Fig. 2b shows a procline pedicle area. Fig. 3-holotype SNM Z 21989-21992 (x 2); **Fig. 5** *Mentzelia halobiarum* (BITTNER); Ostré vŕšky Hill, loc. B_2A , SNM Z 21993 (x 3); **Fig. 6** *Laballa dagysi* sp.n.; Silická Brezová, W of the elevation point 492.2, SNM Z 21994 (x 2)

All figured specimens were coated with ammonium chloride before photographing. The specimens from the Slovak Karst are housed in the collections of the Slovak National Museum in Bratislava (SNM). Photographs by Mr. J. Brožek, Prague.

Slovak Geol. Mag. 4, 2(1998), 137–142

Tectonometamorphic evolution of the Branisko and Čierna hora Mts. (Western Carpathians)

STANISLAV JACKO

Department of Geology and Mineralogy Faculty of Mining, Technical University, Park J. A. Komenského 15, 043 84 Košice, Slovakia

Abstract. Four tectonothermal events have been recognized throughout either Variscan and Alpine tectonometamorphic development within Branisko and Čierna hora Mts., i.e. at the eastern margin of the Western Carpathian Internides realm. Based on palynological and geochronological data the first three Variscan events can be correlated with late Devonian - Early Carboniferous interval. The youngest Variscan event-the consequence of creation of Variscan nappe structure of Tatric and Veporic basement, has been dated to Late-Early Carboniferous boundary.

According to field and geochronological data the first two Alpine tectonometamorphic stages are of pre-Gossau (likely Valangian-Albian) age. The third-the Late Cretaceous one, is probably product of pre -Late Campanian uplift of the Veporic metamorphic dome. The youngest, the post-Eocene event apparently connects with Early Miocene oblique collision of the Western Carpathian Internides with the Northern European Platform.

Key words: Upper and Middle Variscan units, Tatricum and Veporicum units, Variscan and Alpine metamorphism

Introduction

Despite the crosswise position of the Branisko and Čierna hora Mts. in the NE-SW structure of the Western Carpathian Internides (WCl) both the mentioned mountains comprises principal lithostructural suites of the Tatric and Veporic domains (TVD) of the WCI and thus represents direct - the eastern, continuation of the Tatric and Veporic units. Latest geochronological and thermobarometric data obtained throughout the WCl territory and new field mapping and structural results from the Branisko and Čierna hora Mts. region require to reexamine the previous views on tectonometamorphic evolution of the region.

On the basis of the mentioned results this paper reevaluates the available data about the structure, TP conditions and succesive relationships of the Variscan and Alpine tectonometamorphic events of the region with an attemp to synchronize the Alpine events with the Cretaceous development of the VCl Veporic metamorphic dome.

Geological setting

The Branisko and Čierna hora Mts. form the eastern margin of Tatric and Veporic domains of the Western Carpathian Internides (WCl). Their structure comprises two the Late -Variscan basement nappe sheets of the mentioned domains, namely the Upper lithotectonic unit (ULU) and the Middle lithotectonic unit (MLU) sensu Bezák (1994). The ULU consisting of migmatites, gneisses, tiny amphibolite intercalations and granitoid bodies composes the exposed Tatric basement of the Branisko Mts. and the top part of the Veporic basement (the Miklušovce and Bujanová complexes) of the Čierna hora Mts. Lodina complex representing the MLU is outcropped in the axial part of the Čierna hora Mts. basement only. It consists of diaphtoritised gneisses, scarce lensoidal amphibolites and a tiny strip of micaschists rimming the SW flank of the MLU.

Cover sequences are build of Permian to Early Triassic clastic sediments in the Branisko Mts. and by Late Carboniferous to Malmian formations in the Čierna hora Mts. respectively. The units are topped by klippes of the Choč nappe pile and/or by Paleogene and Neogene post-nappe sequences.

In the adjoining Gemeric unit litostratigraphical sequences of the Gelnica unit, Rakovec unit, Klatov nappe unit, Late Carboniferous to Early Triassic cover formations, Meliata (Jaklovce) unit and Silica nappe klippes are present (Fig. 1 a, b, c).

All the units are more or less incorporated into the Alpine NW-SE regionally expressive fold/fault structures which successively culminate into a development of an imbricate melange within the NW-SE Margecany shear zone located between the Gemeric unit and theVeporic unit of the Čierna hora Mts.

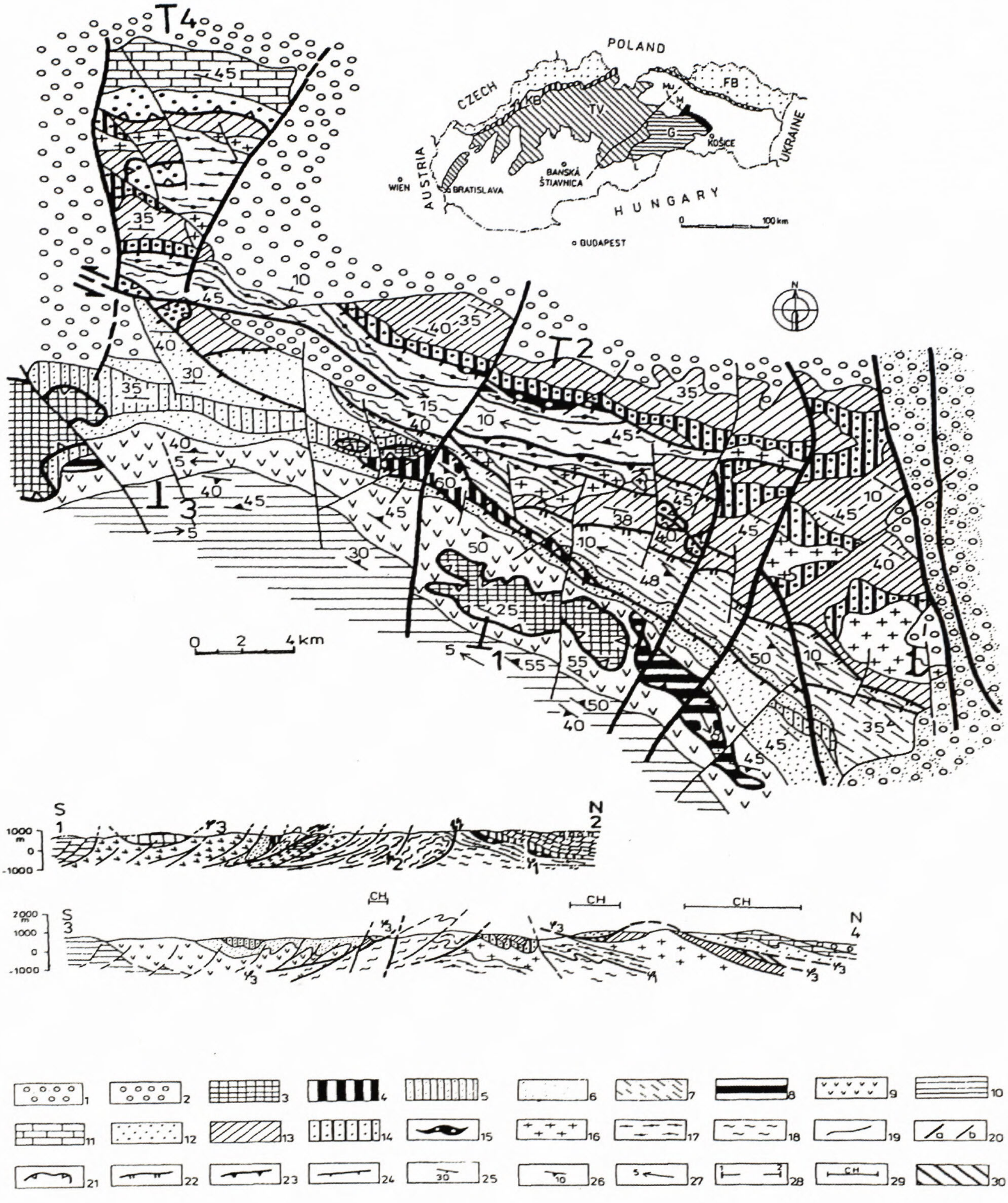


Fig. 1. (a) Position of the studied area in the Western Carpathians.
FB - Flysh Belt, KB - Klippen Belt, TV - Tatricum and Veporicum units, G - Gemericum unit, Mu - Muráň fault, L - Lubenik shear zone, M - Margecany shear zone, black strip - studied area position
Fig.1 (b-c) Geological map and cross sections of the studied area.
1 - Neogene molasse sediments, 2 - Flysh successions of the Intra Carpathian Paleogene, 3 - Silica nappe carbonates, 4 - Sediments and matabasites of the Jaklovce succession of the Meliata unit, 5 - 10 Gemericum unit, 5 - Early Triassic shales, 6 - Permian clastic sediments, rhyolitic volcanites and evaporites, 7 - Carboniferous flysch metabasite sequence with conglomerate and carbonate intercalations, 8 - Klatov group gneisses, serpentinites and amphibolites, 9 - Metabasalts and phyllites of the Rakovec group, 10 - Sandstones, phyllites and rhyolite volcanites of the Gelnica group, 11-12 - Choč nappe of the Hronicum unit,

Thus within 4 to 8 km cross section line nearly all principal structural units of the WCl - and their structural relationships, are observable. Those realities and some biostratigraphical and geochronological data permit a relatively objective successional calibration of tectonometamorphic events - at least of the region.

Variscan tectonometamorphic events

According to palynological and geochronological data (Čorna and Kamenický, 1976, Jacko and Baláž, 1993) metamorphic rocks of both the ULU a MLU are of the Devonian age. Biotitic granodiorites of the ULU (the Bujanová complex) were dated by Ar-Ar method to 334,5 Ma (Maluski et al., 1993). Thrusting of ULU over MLU has ben stated by Dallmeyer (Ar-Ar method, pers.inf.) to 330-312 Ma. Clasts of both mentioned nappe sheets are present within Late Carboniferous cover formation, thus discussed data are the limits for the time interval of four Variscan tectonothermal events recognized within basement units of the region.

TP conditions of the first Variscan tectonometamorphic event of the ULU have been determined by Vozárová, (1993) to 675-770^0 C and 630-870 MPa. They are also indicated by 0-24% pyrope molecule content in garnet cores and by restites of kyanite within ULU gneisses (Vozárová, 1993, Jacko et al.1990).Similar temperatures, but relatively higher pressures were obtained from garnet cores (700^0 C and 1000 MPa of amphibolites (Vozárová - Faryad, 1997) It is usefull to add that mineral assemblage of the event is broadly replaced by the mineral paragenese of the following event within the ULU. Evidently lower TP parameters within the underlying MLU sheet (the Lodina complex) i. e. 520-540^0 C and cca. 300 MPa reveal amphibolite facies metamorphic conditions (Fig.2). According to Korikovskij et al., (1990) Bt+Mu+Pl+Kfs+ Q±Gt is representative mineral assemblage for two-mica gneisses of the event in the MLU, while Hb+Pl+Ilm+ Aph±Q assemblage typical for amphibolites. Bt+ Mu+ Gt +St+Q ±Pl±Andl. form the assemblage of two-mica schists.

The second Variscan tectonothermal event - the periplutonic one, is known from the ULU only. It has very close TP conditions in metamorphic rocks of both the Branisko and Čierna hora Mts. (590-648^0 C and 300-400 MPa, Vozárová (l.c.) and/or 620-625° C and 400-450 MPa, Jacko et al., 1990, respectively). Following Vozárová (l.c.) Gt+Bt+Ksf+Pl±Sil are charakteristic for the Branisko gneisses and migmatites. In the Čierna hora Mts. part of the ULU Jacko et al. (1990) stated the following representative mineral parageneses of this event for typical rock suites: Bt+Pl+Kfs+Q±Gt±Sil for gneisses and migmatites, Hb+Pl+Sph±Cl_z±Ilm±Q for amphibolites and Hb_{Mg}±Phl±Zs±Carb±Serp(Ta?) for rare metaultrabasite bodies.

The third metamorphic events is exclusively bound to relatively narrow exocontact zones of relatively younger autometamorphic granite of the ULU, where its Ksf +Mu ±Pl±Bt paragenese replaces mineral assemblage of the second event and mineral association of biotite granodiorite as well.

The last Variscan tectonometamorphic event producing the diaphtoritic paragenese Q+baueritic Mu+ Chl±Ep, is connected with Early Carboniferous overthrusting of ULU onto MLU. This event - at least partly, diaphtoriticaly homogenized mineral paragenesis of the previous events at green schists facies metamorphic conditions (Fig. 2).

Alpine tectonometamorphic events

The absence of Cretaceous formatios in the cover sequence of the Veporic unit of the region and 135,7 Ma Ar-Ar age obtained from muscovite of the mylonitic granodiorite of the Bujanová complex (Maluski et al., 1993) indicate the begining of the Alpine tectonometamorphic events. Analogously as in the central part of the WCl the intensity of the Alpine metamorphism of the region culminates in its Veporic domain. However, unlike the central part of the Veporic dome (cf. Plašienka, 1997), TP conditions of all-the four (AD_{1-4}) tectonometamorphic events recognized in basement rocks of this domain of the Veporic unit did not overlapp a middle level of the green-schist facies metamorphism. Cover sequences have been metamorphosed at the lower boundary of this metamorphic facies and the Choč nappe pile even at the anchizonal conditions (Korikovskij et al. 1992).

11 - Late Carboniferous clastic sediments, 12 - Triassic and Jurassic carbonates, 13 - 15 Cover sequences of the Tatricum and Veporicum units, 13 - Triassic to Late Jurassic - prevailingly carbonate, successions, 14 - Permian greywackes, shales and rhyolite volcanites, 15 - Late Carboniferous clastic sediments, 16 - 17- The Upper unit of the Variscan structure of the Tatric and Veporic crystalline complex, 16-granitoids of the Patria complex (the Branisko Mts) and the Bujanová complex (the Čierna hora Mts). 17 - migmatites gneisses and amphibolites of the Patria, Bujanova and Miklušovce complexes 18 -The Middle unit of the Variscan structure of the region diaphtoritised gneisses and amphibolites of the Lodina complex (in the Veporic basement only) , 19 - Geological boundaries, 20 - Normal faults, a - regionally significant, 21 - Soles of the Alpine nappes (φ_3 in cross sections only), 22 - Margecany shear zone,23 - Alpine reactivated sole of the Late Variscan nappe (φ_2 in cross sections only), 24 - others important shear zones, 25 - bedding position, 26 - Alpine schistosity orientation, 27 - Alpine fold axes orientation, 28 - Cross sections lines, 29 - Choč nappe extent (in cross sections only), φ_1 - sole of the Late Variscan nappe (in cross section only). 30 - The Križná nappe sequence (in cross section only).

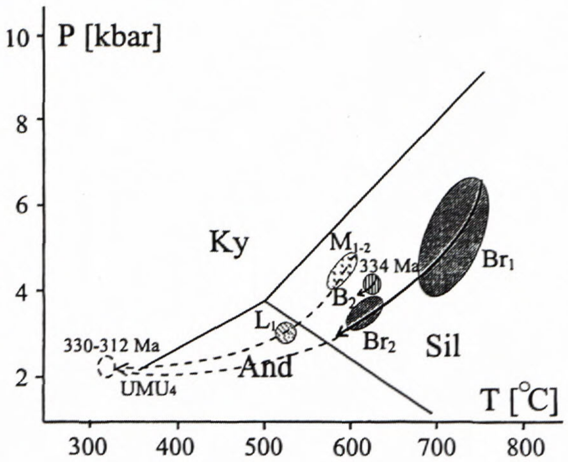


Fig. 2. P-T conditions of the Variscan metamorphism of Upper (Br, M, B) and Middle (L)- the Late-Variscan lithotectonic units of the region. A retrogressive path (dashed) of the fourt Variscan tectonometamorphic event illustrates the Late Variscan green-schists facies convergency of mineral parageneses of both mentioned (UMU) units within their shear-contact zone. Br-metamorphic rocks of the Patria complex (the Tatric unit of the Branisko Mts.) M,B,L-metamorphic rocks of the Veporic unit of the Čierna hora Mts. (M-the Miklušovce complex, B-the Bujanová complex, L-the Lodina complex), 1-4: Succession of the Variscan tectonometamorphic events. See text for further explanations.

Structural products of the first - the pre -Gossau (the AD_1) tectonometamorphic event are both E-W recumbent folding of cover sequence and diaphtoritized suite of the MLU and NNE vergent thrusting of the Choč nappe (Jacko et al. in Polák et al. 1997). Within axial clea- vage set of folded MLU suite and marly Jurassic limestones synkinematic assemblage of chlorite, white mica, quartz and carbonate minerals is locally preserved.

During the AD_2 event all the units of the region, incl.the Choč and Gemeric ones, have been penetratively folded into NW-SE folds. For this event is typical a post-kinematic blastesis of Chl+Mu+Q±Pl±Tourm, assemblage within the folds in the basement units namely in diaphtorites of the MLU.The fold structure of the pre-Tertiary units has been successively shared within regional (e.g.Margecany) reverse shear zones of the same direction.

Within the AD_3 - the pre - Gosau event as well, structures of the NW-SE shear part have been opened for a hydrothermal mineralization and rarely -within wider silicified zones of the MLU basement rocks, resulted into postkinematic growth od Q+Mu+Bi± Ab.

The AD_4 event comprises an expressive, post -Paleogene mainly sinistral wrenching of the previous structure of the region. Dominant strike slip zones within all the units are several 10 m thick, they have NW-SE orientation and moderate to steep dip to SW (Figs.1 b,c). They commonly reactivate reverse shear zones of the AD_2 event. On cleavage planes of the zones synkinematic growth of chlorite, carbonate minerals, white mica and ± quartz assemblage is typical.

Discussion and conclusions

As results from above outlined data the Late Devonian - Early Carboniferous interval documents a very short limit for the Variscan tectonometamorphic development of the region. Following Maluski´s et al. (1993) 334,5 Ma Ar-Ar dating of granodiorite from the Veporic part of the ULU we obtain the upper limit for the first event because sheet-like granodiorite bodies penetrate into schistosity - i.e. into subparallel cleavage set, of the tightly folded metamorphic rocks of the unit. For a comparison it is usefull to add that the granodiorites either petrochemically or in age are very close to better known Veporic granodiorites of the Sihla type (cf. Petrík et al., 1993).

Palynological determination of the Devonian age of the ULU metamorphic rocks of the region (Čorna and Kamenický, 1976) has been dated from gneisses overlying the granodiorite body. As it is known from Bezák´s (1994) definition of the Variscan nappe structure of the TVD, the ULU is a collage of either genetically or in age different rock with a thick complex of paleo-Variscan migmatites (orthogneisses) and-originally, lower crustal, banded amphibolites floored sheet-like granitoid bodies of the ULU (Bezák et al.1997, Hovorka et al., 1992, Janák et al., 1993). From this point of view it is possible that some lamellae of relatively younger rock suites are present within gneissic-migmatitic complex of the ULU. Nevertheless, before the emplacement of granitoides, the whole suite of the ULU have been either tightly folded into E-W folds or synkinematically metamorphosed at amphibolite to granulite facial conditions (Vozárová 1993, Janák et al., l. c., Bezák et al., l. c.). Structural parameters of this event reveal its formation in a simple shear regime (Jacko et al., 1997). Typical structures of the event are tight, rootless cm-dm folds. Their axial plane cleavage set practically obliterates the earlier structures.

A very close linkage of the second Variscan metamorphic event to the granitoid bodies emplacement is indicated by: (i) a gradual increase of migmatitization phenomena towards granodioritic bodies (Jacko, 1978), (ii) - a substitution of kyanite by sillimanite and by evolution of garnet retrograde rims in gneisses (Jacko et al., 1990, Vozárová, l.c.), (iii) - a mimetical growth of phyllosilicates of the event onto schistosity planes of the rocks (Jacko, l.c.). The temperature of the event in the Veporic part of the region - i.e. 630-625 °C correlates to initial temperatures of granodioritic melt - i.e. 850-600 °C, gained from analytical researches of zonal zircons (Jablonská, 1993). The age of the event is comparable to the 334,5 Ma obtained by Maluski et al. (1993) from the same granitoide body.

The third metamorphic event associates with an emplacement of relatively younger muscovite granite body into the ULU sheet. Except of the mentioned informations its alkali fedspar saturated liquidus phase resulted into formation of polymigmatitic aureoles at the contact with migmatites of the previous event. Large monomineral K-feldspar porphyroblasts are charakteristic for this event in polymigmatites.

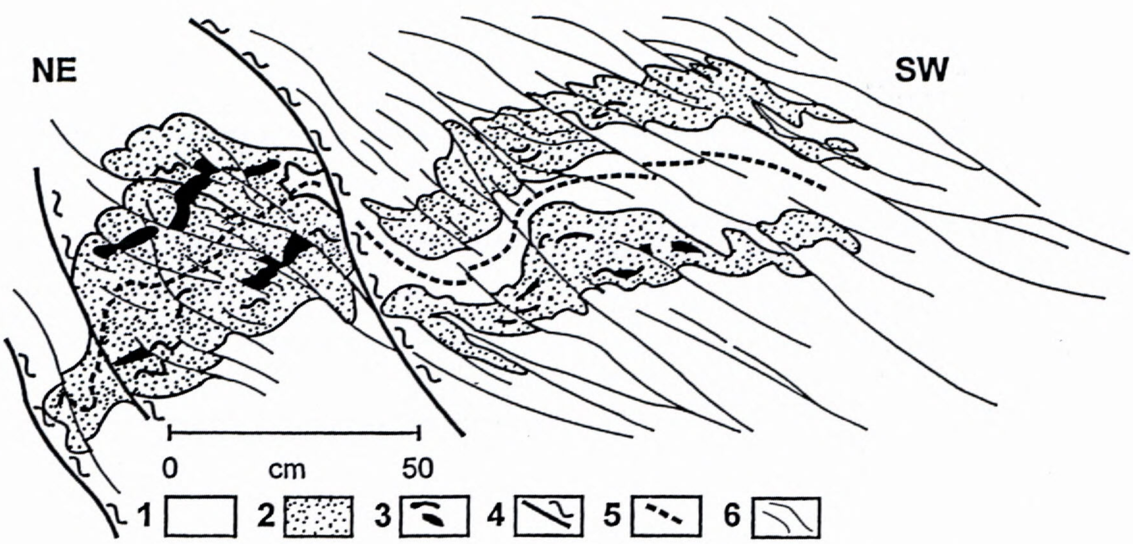


Fig. 3. An example of the Late Variscan - Alpine polystage reworking of the metamorphic suite of the Lodina complex - the Middle Lithotectonic unit of the Variscan structure of the region. Early Alpine (AD_1) isoclinal folding of the Late Variscan secretional quartz lenses and succesive (AD_2) refolding of the E-W folds into regionally penetrative NW-SE fold structures, finally sheared by axial plane cleavage as a consequence of a reverse thrust kinematics of regional shear zones of the Margecany type. The post - Paleogene sinistral shearing reactivation of the zones has produced a mullions formation within the closures of the interfered fold sets (NE part of the figure). 1-diaphtoritised gneisses, 2- secretional quartz, 3-gneisses inclusions within the quartz, 4-axial plane of the Paleo-Alpine fold, 5-dislocations, 6-axial plane cleavage of the NW-SE fold set.

The fourth Variscan event dated to 330-312 Ma (Dallmeyer, pers.inf.) - by the way firstly at the WCl realm, is also detectable geologically. Clasts of both ULU and MLU rocks are present in Late Carboniferous formations of the cover sequence of the Čierna hora Mts. (Korikovskij et al., 1989). A high content of secretional quartz boulders within conglomerates of the formation indicates either synkinematic (diaphtoritic) stage of the event or a rapid pre-Late Carboniferous uplift of the basement units. Following Fritz et al. (1992) we suppose that this green-schist facies event terminates the development of the Variscan nappe structure at the Tatric and Veporic domains of the WCl.

The begining of Alpine tectonometamorphic development in the region is only evidenced by 137,5 Ma Ar-Ar dating of white micas from mylonitized granodiorite of the Veporic part of the ULU (i.e. from the Bujanová complex). The analysed sample was taken from the Bujnisko shear zone (Jacko, 1978) of the NW - SE direction and a moderate dip to SW. The zone is one of pendants of the Margecany shear zone of the same spatial position which rhytmically shear either Veporic and adjoinig Gemeric units (Fig. 1a,b,c). Although kinematically diferent reactivation of the zones during Cretaceous, Miocene and even recent periodes was proved (cf. Jacko et al., 1996) a reality of the Maluski's et al. (l. c.) data also could confirm absence of Early Cretaceous cover formation in the region.

According to Plašienka's (1997) the Cretaceous development of the Veporic metamorphic dome started as the conseguence of burial of its basement and cover formations before 150-130 Ma (Tithonian - Hauterivian). The begining of thrusting and cover shortening at the southern margin of the dome ceased in Early Cretaceous (l.c.). Into this period we locate the first Alpine (AD_1) tectonometamorphic event of the region - i.e. E-W recumbent folding of the MLU basement rocks (incl. secretional quartz layers of the last Variscan event, Fig. 3) and its cover sequence. The formation of subhorizontal cleavage set within the units and a synkinematic growth of chlorite and white micas on them belong likely to the final stage of the event. From white micas in structurally analogous cleavage planes of both palynspaticaly and litofacial content very close the Veľký Bok cover sequence of the central part of the WCl Veporicum unit, Nemčok and Kantor (1989) determined by K-Ar method 101 Ma. For those and other reasons we suppose the Valangian-Albian interval as the time limit for AD_1 deformation stage inclusively the Choč nappe thrusting in the region as well.

A penetrative development of structural and metamorphic assemblages of AD_2 deformation stage throughout the units of the region indicate a thermodynamic culmination of its Alpine tectonometamorphic development. Greenschist facies mineral assemblage (cf. previous chapters) synkinematically growing within NW-SE folds of diaphtoritised MLU (i.e. the Lodina complex) rocks represents thermal climax in this ductilised environment due to overloading by the paleo-Alpine nappe sheets. Anchizonally metamorphosed formations of the Choč nappe are also included into the folds.

The termination of the AD_2 event represents a reverse thrust shortening in the shear zones of Margecany type. The zones penetratively split the NW-SE fold structure of the units into SE vergent monoclinal sheets. Mylonites of the units (incl. cover and Choč nappe formations) occur among clasts of basal (i.e. Eocene) conglomeates of the Intra-Carpathian Paleogene sequence. According to 84-88

Ma cumulation of Ar-Ar geochronological ages of either analogous shear zones or Veporic cover formations of the northern part of the central Veporic zone (Dallmeyer et al., 1993, 1995) we suppose the Late-Coniacian-Early–Campanian reverse thrust activity in the zones of the region.

The third - the Upper Cretaceous extensional AD_3 deformation stage is marked by hydrothermal mineralization filling of the mentioned shear zone structures and by postkinematic growth of Q+Mu+Bi±Ab±Chl paragenese in some silicified parts of those structures. This age also corresponds to temperatures of ore solutions in the neighboring Gemeric unit (150-300^0 Rojkovič in Cambel - Jarkovskij et al.,1985) and testify the formation of hydrothermal veins of the region before its Late - Campanian uplift into cca. 19 km depth as results from 73 Ma FT age of zircon from Čierna hora Mts. granodiorite (Kováč et al., 1994).

Duplexes of Intracarpathian Paleogene formations within paleostress - analyse verified mainly sinistral wrench zones (cf. Jacko et al., 1996) reveal either an intensive post-Paleogene reactivation or formation new NW-SE shear zones in the units of the region. Their SW steeply dipping fault and cleavage planes lead to broad homogenization of the final structure of the region - as is also seen in the upper part of recently shot deep seismic profile G (Vozár et al., 1995). At the ductilely different media of the MLU-the Lodina complex, rocks mullions structures are formed in the AD_2 event refolded more competent secretional quartz layers (Fig.3). This AD_4 event have been likely developed due to eastward escape of the Western Carpthians form the Eastern Alps.

References

Bezák V. 1994: Proposal of the new dividing of the West Carpathians crystalline complexes based on the Hercynian tectonic building reconstruction. Mineralia Slov., 26, 1, 1-6 (in Slovak).

Bezák V., Jacko S., Janák M., Ledru P., Petrík I. & Vozárová A. 1997: Main Hercynian Lithotectonic units of the Western Carpathians. In Geological evolution of the Western Carpathians (Eds. Grecula P., Hovorka D. & Putiš M.), D. Štúr Publ. Bratislava, 1-8 (in print).

Čorná O. & Kamenický L. 1976: Ein Beitrag zur Stratigraphie des Kritallinikums der Westkarpaten auf Grund der Palynologie. Geol. Zbor. Geol. carpath., 27, 1, 117-132.

Dallmeyer R.D., Neubauer F. & Putiš M. 1993: $^{40}Ar/^{39}Ar$ mineral age controls for the Pre-Alpine and Alpine tectonic evolution of nappe complexes in the Western Carpathians. In: Pitoňák P. & Spišiak J. (Eds.): Pre-Alpine events in the Western Carpathians Realm, 11-20.

Dallmeyer R. D., Neubauer F., Handler R., Fritz H., Mueller V., Pana D.& Putiš M. 1995: Tectonothermal evolution of the internal Alps and Carpathians: Evidence from $^{40}Ar/^{39}Ar$ mineral and whole rock data. Eclogae geol. Helv. 89, 203-227.

Fritz H., Neubauer F., Janák M. & Putiš M. 1992: Variscan mid-crustal thrusting in the Carpathians. Part II: Kinematics and fabric evolution of the Western Tara basement. Terra Nova abstr. Suppl. 24, 24

Hovorka D., Méres Š & Ivan P. 1993: Geodynamic setting of the main pre-Alpine basement complexes: The Western Carpathians. Geol. Carpathica 44, 4, 258.

Jablonská J. 1993: Charakterization of zircons from granitoid rocks of the Čierna hora Mts. (Western Carpathians). Mineralia Slov., 25, 3, 157-171 (in Slovak).

Jacko S. 1978: Lithological - stuctural charakteristics of the central part of the Čierna hora Mts. Západ. Karpaty, Sér. Geol. 3, 59-80. (in Slovak).

Jacko S., Korikovskij S., & Boronichin A.V. 1990: Equilibrium assemblages of gneisses and amphibolite s of the Bujanová complex (Čierna hora Mts.), Eastern Slovakia. Mineralia Slov., 22, 3, 231-239. (in Slovak).

Jacko S., Baláž B. 1993: New knowledge about the Čierna hora Mts. metallogenese (Western Carpathians). Mineralia Slov., 25, 232-326. (in Slovak).

Jacko S., Sasvari T., Zacharov M., Schmidt R. & Vozár J. 1996: Contrasting styles of Alpine deformations at the eastern part of the Veporicum and Gemericum units, Western Carpathians, Slovak Geol. Magazine, 2, 150-164.

Jacko S. Vozár J. & Polák M. 1997: Tectonics. In Explanations to geological map of the Branisko and Čierna hora Mts. 1:50 000 (Ed. Polák M.). D. Štúr Publ., Bratislava, 124-148.

Jacko S. Hók J. & Madaras J. 1997: Pre- and syn-granitoid deformations of the Western Carpthians metamorphic complexes. In Geological evolution of the Western Carpathians (Eds. Grecula P. Hovorka D. and Putiš M.) D. Štúr Publ., Bratislava, 1-14 (in print).

Janák M., Bezák V., Broska I., Fritz H., Kahan Š., Kohút M., Neubauer F., O´Brien P.J., Onstott T., Reichvalder P. and Uher P. 1993: Deformation, metamorphism an granitoid magmatism in the Tatry Mts. (Central West. Carpathians, Tatric unit.): records of Variscan and Alpine orogeny. In: Pitoňák and Spišiak, (Eds.): Pre-Alpine events in the West. Carpathians Realm, Excur. Guide, AEWCR, Stará Lesná, 51-61.

Korikovskij S. P., Jacko S., Boronichin V. A. 1989: Alpine anchimetamorphism of Upper Carboniferous sandstones from the sedimentary mantle of the Čierna hora Mts. Crystalline complex (Western Carpathians). Geol. Journ. Geol. carpath. 40, 5, 579-598.

Korikovskij S.P. Jacko S. Boronichin V.A. 1990: Facial conditions of Variscan prograde metamorphism in the Lodina complex of Čierna hora crystalline. Mineralia slov., 22, 225-230.

Korikovskij S. P., Jacko S., Boronichin V.A., Šucha V. 1992: Ilitte-paragonite layer intergrowths from the Gemericum nappe in the SE part of the Čierna hora Mts. Veporicum (Western Carpathians). Geo. Journ., Geol. carpath., 43, 1, 49-55.

Kováč M., Kráľ J., Márton E., Plašienka D., & Uher P. 1994: Alpine uplift history of the Central Western Carpathians: geochronological, paleomagnetic sedimentary and strucural data. Geol. Carpath., 45, 83-96.

Maluski H., Rajlich P. and Matte Ph. 1993: $^{40}Ar/^{39}Ar$ dating of the Inner Carpathians Variscan basement and Alpine mylonitic overprinting. Tectonophysic, 223, 313-337.

Nemčok M. & Kantor J. 1989: A movement study of selected part of the Veľký Bok unit: Region. geol., Spr. o výsk., 25, GÚDŠ, Bratislava, 75-82.

Plašienka D. 1997: Tectonochronology and paleotectonic model of Jurassic - Cretaceous evolution of the Central Western Carpathians. Manuscript-Habilit. theisis, Faculty of Sciencis, Comenius Univ., Bratislava, 1-188.

Petrík I. Broska I. Uher P. & Kráľ J.: 1993: Evolution of the Variscan granitoid magmatism in the Western Carpathians realm. Geol. Carpath. 44, 4, 265-266.

Rojkovič I. 1985: Paragenesis and succession of ore mineralisation. In the Rudňany ore field (Eds. Cambel B. & Jarkovski J.) VEDA Publ., Bratislava, 183-193.

Vozár J., Tomek C., Vozárová A. & Dvořáková V. 1995: Deep seismic profile G: geological interpretation (Inner Western Carpathians, Slovakia), Contrib. of the 3rd Annual meeting of IGCP Project 356. Plate Tectonic Aspects of Alpine Metallogeny in the Carpatho-Balkan Region, 1-3.

Vozárová A. 1993: Pressure-temperature conditions of metamorphism in the northern part of the Branisko crystalline complex. Geol. Carpath. 44, 4, 233-249

Vozárová A. & Faryad S.W. 1997: Petrology of Branisko Crystalline rock Complex. CBGA - Commision on Metamorphism Meeting. Budapest 31-26.

• Discussion

Critical remarks to the article of Soták et al. (1996)

MICHAL POTFAJ[1]

Geological Survey of Slovak Republic, Mlynská dolina 1 817 04 Bratislava

Soták, Bebej and Biroň (1996) describe the deep-sea fan sediments of the Levočské vrchy Mts., as indicators of a „collision-orogene regime". For recognizing such deposits they used as criteria the occurrence of some sandstone beds enriched in ophiolitic (serpentinic) detritus, located at the „perisutural" Šambron-Kamenica zone. The petrographic composition of these beds the authors interpret as arenites related to a magmatic- or oceanic-arc. Their age was designated as Late Oligocene.

In cited article the authors fail to acknowledge the principal previous works by many authors, although they use those results. For example, the authors use some formation names that are new (Kluknava-, Kežmarok-, Tomášovce Member) or those with different meaning by different authors (Šambron Beds), neither referring to the original papers (Filo and Siráňová 1996, Filo et al. 1994, 1995, Gross et al. 1994-1996), nor to the source of the drill hole information (Nemčok et al. 1977, Rudinec 1979, 1986, Kullmanová and Rudinec 1988, Píchová and Kudělásková 1989). They also seem unawared several sedimentological analyses (e.g. Marschalko 1962, 1978, Krysiak 1976, Radomski 1958-9), and paleontological researches (Nemčok and Vaňová 1977, Nemčok et al. 1990, Oszczypko 1996).

Through this lack of familiarity, some of the paleogeographical interpretations became quite questionable, methodically deficient and terminology used is inadequate at places. These shortcomings are pointed out below.

Soták and Bebej (1996) published already some basic definition of the Šambron Beds with their serpentinic sandstones, but in actual paper is missing more detailed description of the facies character and analysis on which their succeeding reconstructions were based. Thus, the inferred paleotectonic setting remains speculative. Using inappropriate terms the authors lead to a false conclusion. For example, one on their page 346 they state that „*... the top sandstone lithosomes... representing the final stage... referred to as suprafan*", and further „*...progressive progradation of (the) cone in the stage of suprafan development...*", which is misleading. The *suprafan* is a morphological term related to facies definition and as such it cannot be used to designate the stage of development.

Authors mention the conglomerates, whose position within the Šambron Beds in the paper is left uncertain. This position is even more obscure since in their previous publication (Soták & Bebej 1996) the conglomerates are completely omitted in the scheme (l.c. Fig. 1 and 4). The location of the serpentinic sandstones on the Nemčok's map (1990) is all within the Šambron beds, but outside of the conglomerate suite.

Another obscure term is the so-called *Šambron zone* (their p. 346). Does this term refer to a sedimentary basin or to a tectonic zone? If it designate tectonic zone then the position of the conglomerates may be interpreted also outside of their „Šambron Beds". Several different usages of „Šambron Beds" occur (Chmelík 1959, Chmelík in Buday et. al. 1968, Koráb et al. 1962, Marschalko 1975, Nemčok et al. 1977, 1990, Leško et al. 1979, Koráb 1986, Mastella et al. 1988), so it is unclear which significance is used.

The correlation of the Šambron Beds with the Szaflary Beds of the Podhale region is also disputable. The Szaflary Beds besides the flysch framework, contain numerous conglomerate beds (Mastella 1975, Mastella et al. 1977). Paradoxically, if Soták et al. (1996) consider the Šambron Beds to be Late Oligocene, then these can not be correlated with the Szaflary Beds, which, according to paleontological determinations, are older (Priabonian) (Bieda 1959, Mastella et al. 1977).

The age of the Šambron beds given by Soták et al. (1996) provides another problem, that affects their paleogeographic interpretation. At first it is necessary to analyse the original determination of the Šambron Beds age. Their „Late Oligocene" was designed on the basis of Nagymarosy's determination of three nannoplankton species, as reported in Soták and Bebej (1997). Two of these fossils are *Cyclicargolithus abisectus* and *Reticulofenestra lockeri*, which are not restricted to the Late Oligocene exclusively. The *C. abisectus* was also found in the older sediments, the Inner Carpathian Paleogene inclusive (Dudziak 1983, 1990, Birkenmajer & Dudziak 1988, Bystrická 1979, Bubík 1996, Oszczypko 1996, Potfaj and Raková 1989). Furthermore *R. lockeri* may be a synonym to *Cribrocentrum reticulatum*, which is a Middle Eocene taxon (Bubík 1996, Oszczypko 1996). The third cited fossil, *Zygrhablithus bijugatus*, is common Early Eocene to Late Oligocene species (Perch-Nielsen 1986). Thus, reffering to faunal data the proposed Late Oligocene age of the Šambron Beds is not sufficiently proved. It is more likely that the Šambron Beds are Late Priabonian – Early Oligocene as was determined on the basis of numerous foraminiferal and nannoplankton associations by Bieda (1959), Vaňová (1962, 1964), Snopková (1989), Nemčok et al. (1990), or Dudziak (1983, 1993).

To make a paleogeographic reconstruction more reliable, one should also include observations on marine paleocurrent directions. Even when the authors do not posses their own data, they should use that of previous studies (Marschalko 1975, Radomski 1958, 1959, Krysiak 1976, Koráb et al. 1962). This added data indicate a transport of detritus longitudinal to the basin axis. Therefore, it can neither be interpreted as coming from the „*slopes of the active Central Carpathian plate*", nor from the „*northern collisional edge*".

When Soták et al. (1996) suggest a single ocean in the realm of the Magura basin, joined to the Inner Carpathian Paleogene basin, how can they explain the presence of „ophiolitic detritus" on the side of the Inner Carpathians in the Šambron Beds (according to the authors – Late Oligocene), without leaving a trace of it in the Malcov Formation of Magura basin? The source of the ophiolite detritus in the zone of the plate boundaries is unrealistic.

Also unexplained remains the „convergent extensional model" with „perisutural basin" introduced in their Fig. 2. Terms „convergent" and „extensional" used in this way seem to be contradictory.

A palinspastic reconstruction of segmented blocks of the ocean crust derived from a subduction scar, their subsequent uplift to erosion level (Soták and Bebej 1995), and then the detritus transport to a single local sand-lobe deep on the same ocean floor seems speculative, if not unrealistic. What kind of morphological and structural body could such a source be? An intra-oceanic perisubductional cordillera is not known today. Where is there an analog?

In this context the interpretation of different sources for some clasts in the conglomerates of the Šambron Beds, designed as Iňačovce-Kričevo unit (their p. 346), is practically impossible. Following the author's definition given elsewhere (Soták et al. 1993) in the stratigraphic pile of the Iňačovce-Kričevo unit also occur Middle Eocene sediments, and these are metamorphosed. Now, if the metamorphism took place sometimes during the Savic (but certainly not earlier than Pyreneic) phase then the succession of geological processes implies that Iňačovce-Kričevo unit could neither have been exposed at the time of sedimentation of the Šambron Beds, nor served as a source for the Šambron conglomerates.

A valid paleogeographic reconstruction could not work without incorporating the Klippen Belt into the scheme. The principal structures of the Klippen zone were already formed in the Middle Eocene and Oligocene. These structures served as a local source for the material of the Szaflary Beds (Mastella 1975). On the Laramian structures of the Klippen zone, there transgressed the clastics of the „Klippen Paleogene" (Scheibner in Buday et al. 1968, Birkenmajer 1956, 1965, 1970, Potfaj in Žec et al. 1997, Potfaj et al. 1991, 1993, Potfaj 1997).

Taking into account the paleogeographic configuration of the land-masses and ocean-basins, their geological arrangement and marine paleocurrent system, we should rather search for the source of serpentinite detritus in the sandstones of the Huty Formation somewhere on the southern continent. The small ultrabasic body near Sedlice is out of question, because its age is, according to Marschalko (1962), much younger. Larger southern land-mass source is indicated also by the pollen spectra identified from the Šambron Beds (Snopková 1989). In addition, organic carbon analyses of the Inner Carpathian Paleogene sediments testify that the organic matter was derived from dry-land higher plants (Masaryk et al. 1995).

References

Baráth, I., Bebej, J., Bizoň, A., Hrnčárová, M., Hudáčková, N., Hurai, V., Kohútová, J., Kováč, M., Marko, F., Marschalko, R., Michalík, J., Milička, J., Mišík, M., Pitoňák, P., Pereszlényi, M., Plašienka, D., Prokešová, R., Reháková, D., Soták, J., Spišiak, J., et al. 1996: Zhodnotenie geologickej stavby Levočských vrchov; čiastková záv. správa 1992-1996, časti 1-4. In: Rudinec, R., Magyar, J. et al. (Eds.), Záverečná správa Flyš východného Slovenska - Geofyzika, štúdia za r. 1985 - 1996; GU SAV Bratislava, Nafta Gbely-Michalovce; 1-1193. In Slovak.

Bieda, F. 1959: Palaeontological stratigraphy of the Tatra Eocene and of the Podhale flysch -Engl. Summ. Biul. Inst. Geol., Warszawa, 5 (149), 215-224.

Birkenmajer, K., 1956: Sedimentacionnaja charakteristika jarmutskich (mastrichtskich) slojev v pieninskoj klipovoj zone (Centralnye Karpaty). Bull. Acad. Pol. Sci., ser. Sci. Ter., Varsovie, 4, 721-727.

Birkenmajer, K., 1965: Zarys budowy geologicznej pieninskiego pasa skalkowego Polski. Ann. Soc. Geol. Polon., Krakow, 35, 327-356.

Birkenmajer, K., 1970: Pre-Eocene fold structures in the Pieniny Klippen belt (Carpathians) of Poland Engl. Summ.). Stud. Geol. Polon., 31, 7-81.

Birkenmajer, K., Dudziak, J. 1988: Nannoplankton dating of terminal flysch deposits (Oligocene) in the Magura basin, Outer Carpathians. Bull. Acad. Pol. Sci., ser. Sci. Ter., Varsovie, 36, 1-13.

Bubík, M. 1996: Low diversity calcareous nannoplankton assemblages from the Oligocene Šitbořice Member of the Menilitic Formation (West Carpathians, Czechoslovakia) from Bystřice nad Olší. Knih. ZPN, Hodonín, 14b, 223-245.

Buday, T., Cicha, I., Fusán, O., Hanzlíková, E., Chmelík, F., Kamenický, J., Koráb, T., Kuthan, M., Maheľ, M., Matějka, A., Nemčok, J., Pícha, F., Roth, Z., Seneš, J., Scheibner, E., Stráník, Z., Vaškovský, I., Žebera, K. 1968: Regional geology of Czechoslovakia; part II - The West Carpathians. Academia, Praha; 1-723 p.

Bystrická, H. 1979: Middle-Oligocene calcareous nannoplankton in the Banskobystrická kotlina (depression). Z.K. - Paleont., 4, 123-145.

Dudziak, J. 1983: Stratigraphy of the Podhale Flysch (Palaeogene), Central Carpathians, based on calcareous nannoplankton. I: The Zakopane Formation of the Bialy Dunajec and Bialka river valleys. Stud. Geol. Polon., 77, 55-81.

Dudziak, J. 1986: Stratigraphy of the Podhale Flysch (Palaeogene), Central Carpathians, based on calcareous nannoplankton. III. The Chocholow and Ostrysz Formations -Engl. Summ. Stud. Geol. Polon., 88, 157-174.

Dudziak, J. 1993: Age of the Podhale Flysch (Palaeogene) at Kacwin, south of the Pieniny Klippen Belt, Carpathians, based on calcareous nannoplankton -Engl. Summ. Stud. Geol. Polon., 102, 159-176.

Filo I., Maglay J., Mello J., Vozár J., Jetel J., Raková J., Samuel O., Siráňová Z., Snopková P., 1994: Vysvetlivky ku geologickým mapám 1:25000, listy M-34-113-B-a Hranovnica, M-34-113-B-b Hrabušice, M-34-114-A-a Spišská Nová Ves. GÚDŠ, Bratislava. (In Slovak)

Filo I., Mello J., Maglay J., Siráňová Z., Jetel J., Kováčik M., 1995: Vysvetlivky ku geologickej mape 1:25000, listy Spišská NováVes, Spišský Hrušov, Nálepkovo, Rudňany. GSSR, Bratislava. (In Slovak)

Filo I., Siráňová Z., 1996: The Tomášovce Member - a new lithostratigraphic unit of the Subtatric Group -Engl. Summary. Geol. prace - Spravy, GÚDŠ Bratislava 102. 41-49 p.

Gross P., Buček S., Borza V., Ďurkovič T., Filo I., Halouzka R., Janočko J., Karoli S., Kováčik M., Lukáčik E., Maglay J., Mello J., Nagy A., Polák M., Spišák Z., Vozár J., Žec B., Jetel J., Raková J., Samuel O., Siráňová Z., Túnyi I., Zlinská A., Žecová K., Snopková P., 1996: Vysvetlivky ku geologickej mape Popradskej kotliny, Hornádskej kotliny, Levočských vrchov a šarišského paleogénu. GSSR, Bratislava. pp: 1-162. (In Slovak)

Gross P., Halouzka R., Ďurkovič T., Siráňová Z., Jetel J., Spišák Z., Samuel O., Snopková P., Raková J., 1994: Vysvetlivky ku geologickej mape 1:25000; listy M-34-101-D-c Poprad, M-34-101-D-d Spišský Štrvrtok, M-34-101-B-c, M-34-101-D-a Veľká Lomnica, M-34-101-D-b Kežmarok, M-34-101-B-c Tatranská Lomnica. GÚDŠ, Bratislava. (In Slovak)

Gross P., Ďurkovič T., Jetel J., Kováčik M., Samuel O., Žecová K., Tunyi I., 1995: Vysvetlivky ku geologickej mape 1:25000, listy M-34-102-C-a Ľubické Kúpele, M-34-102-C-b Torysky, M-34-102C-c Levoča, M-34-102-C-d Jablonov. GSSR, Bratislava. (In Slovak)

Chmelík, F. 1959: Zpráva o geologických výzkumech centrálně karpatského paleogénu v Šariši mezi Šambronem a Sabínovem. Zpr. geol. vyzk. r., 1957, 81-83. (In Czech).

Koráb, T. 1986: Výskum vnútrokarpatského paleogénu a jeho podložia v Šarišskej vrchovine a v Levočskom pohorí. Záverečné naftovo-geologické zhodnotenie oblasti na základe vrtu Šariš-1. GÚDŠ, Bratislava; 29 p. (In Slovak).

Koráb, T., Nemčok, J., Ďurkovič, T., Marschalko, R. 1962: General investigation of oriented sedimentary structures in East-Slovakian Flysch -Engl. Summ. Geol. sborn. SAV, Bratislava, 13, 257-274.

Krysiak, Z. 1976: Directions of the Transport of material in the Podhale flysch on the basis of data from the basin of the Lesnica stream /Eastern Podhale -Engl. Summ. Kwart. Geol., Warszawa, 20/2, 323-330.

Kullmanová, A., Rudinec, R. 1988: Paleogene sequence and its Mesozoic underlier in the Spišsko-šarišské medzihorie Mts. (The Plavnica-1 drilling) -Engl. Summ. Mineralia slov., 20, 455-461.

Leško, B., Nemčok, J., Ďurkovič, T., Gašpariková, V., Kullmanová, A., Vaňová, M., Snopková, P., Harča, V. 1979: Oporný vrt Lipany-1, záverečné geologické a naftovo-geologické vyhodnotenie. GÚDŠ, Bratislava; 1-15 p. In Slovak.

Marschalko, R. 1962: Stratigraphische Studien im Flysch nördlich des Gebirges Čierna Hora -German Res. Geol. práce, Zošit, 63, 15-22.

Marschalko, R. 1975: Depositional environment of conglomerate as interpreted from sedimentological studies... -Engl. Summ. Nauka o Zemi, Geol., 9, 1-145.

Marschalko, R. 1978: Evolution of sedimentary basins and paleotectonic reconstruction of the West Carpathians -Engl. Summ. In: Vozár, J. (Ed.), Paleogeografický vývoj Západných Karpát; GÚDŠ, Bratislava; 49-80.
Masaryk, P., Milička, M., Pereszlényi, M., Pagáč, I. 1995: Niektoré výsledky geofyzikálnych, geochemických a litofaciálnych výskumov v paleogéne Levočského pohoria. In: Kaličiak, M. (Ed.), III.Geologické dni Jána Slávika (Zborník referátov); GÚDŠ, Bratislava; 47-54. (In Slovak)
Mastella, L. 1975: Tektonika fliszu we wschodniej czesci Podhala. Ann. Soc. Geol. Polon., Krakow, 45, 3-4.
Mastella, L., Arendanski, A., Kicana, J. 1977: Zastosowanie analizy zmiennosci niektorych cech litologicznych do wyznaczania i korelacji ogniw litostratygraficznych we fliszu podhalanskim (Engl. Summ.). Przegl. Geol., Warszawa, 25, 19-22.
Mastella, L., Ozimkowski, W., Szcesny, R. 1988: Tectonics of the northwestern Podhale flysch -Engl. Summ. Przegl. Geol., Warszawa, 36/10, 566-572.
Nemčok, J. 1990: Geologická mapa Pienin, Čergova, Ľubovnianskej a Ondavskej vrchoviny. Regionálne geologické mapy Slovenska 1:50 000, 1-2. (In Slovak).
Nemčok, J., Vaňová, M. 1977: Redeposition of larger forаmininifers in East Slovakian Flysch Belt. Geol. práce, Správy, GÚDŠ Bratislava, 67, 105-134.
Nemčok, J., et al. 1977: Štruktúrny vrt PU-1 Šambron (Ľubovnianska vrchovina). Reg. geol. ZK, 8, 1-72. (In Slovak).
Nemčok, J., Zakovič, M., Gašparíková, V., Ďurkovič, T., Snopková, P., Vrana, K., Hanzel, V. 1990: Vysvetlivky ku geologickej mape Pienín, Čergova, Ľubovnianskej a Ondavskej vrchoviny v mierke 1:50 000. GÚDŠ, Bratislava; 1-131 p. (In Slovak).
Oszczypko, M. 1996: Calareous nannoplankton of the Globigerina marls (Leluchów marls member), Magura nappe, West Carpathians. Ann. Soc. Geol. Polon., Krakow, 66, 1-15.
Perch-Nielsen, K., 1985: Cenozoic calcareous nannofossils. In: Bolli, H.M., Saunders, J.B., et al. (Eds.), Plankton stratigraphy; Cambridge Univ. Press, Cambridge; 427-554.
Píchová, E., Kudělásková, J. 1989: Fyzikální vlastnosti hornin vrtu Plavnica 2. Geofyzika, Brno; 2-26 p.
Potfaj, M., 1997: Relation of the Klippen belt and the Flysch zone in the territory of western Slovakia. In: eds. Plašienka D., Hók J., Vozár J., Elečko M., Alpine evolution of the Western Carpathians and related areas. Dionýz Štur Publishers, Bratislava. pp: 119-125.
Potfaj, M., Ďurkovič, T., Kohút, M., Raková, J., Samuel, O. 1993: Vzťah panví na styku Vonkajších a Vnútorných Karpát. GÚDŠ, Bratislava; 1-35 p. (In Slovak).
Potfaj, M., Köhler, E., Ďurkovič, T., Gross, P., Samuel, O. 1991: Pribradlový flyš terchovskej a oravskej oblasti. GÚDŠ, Bratislava; 1-28 p. In Slovak.
Potfaj, M., Raková, J. 1989: Vyhodnotenie nanoplanktónových spoločenstiev zo vzoriek z vrtu FPJ-1. GÚDŠ, Bratislava; 1-5 p. (In Slovak).
Radomski, A. 1958: The sedimentological character of the Podhale flysch -Engl. Summ. Acta geol. Polon., 8, 335-409.
Radomski, A. 1959: Podhale flysch sedimentation -Engl. Summ. Biul. Inst. Geol., Warszawa, 5 (149), 251-257.
Rudinec, R. 1979: Naftovo-geologické zhodnotenie oporného vrtu Lipany-1 a termálne vody. In: Leško, B., Nemčok, J. (Eds.), Oporný vrt Lipany-1, záverečné geologické a naftovo-geologické vyhodnotenie; GÚDŠ, Bratislava; 1-13. In Slovak.
Rudinec, R. 1986: Štruktúra Lipany a niektoré zaujímavé geologické a ropno-geologické výsledky. ZPN, Hodonín, 31,4, 521-527. (In Slovak).
Snopková, P. 1989: Biostratigrafia Ľubovnianskej vrchoviny na základe mikroflóry. In: Samuel, O. (Ed.), Zborník z paleontologickej konferencie; GÚDŠ, Bratislava; 153-167. (In Slovak).
Soták J., Bebej J., Biroň A., 1996: Detrital analysis of the Paleogene flysch deposits of the Levoča Mts.: evidence for sources and paleogeography. Slovak geological Mag. 3-4. 345-349 p.
Soták, J., Bebej, J. 1996: Serpentinic sandstones from the Šambron-Kamenica zone in Eastern Slovakia: evidence of deposition in a Tertiary collisional belt. Geol. Carpathica, 47, 4, 227-238.
Soták, J., Spišiak, J., Biroň, A. 1993: Position of the Pozdišovce-Iňačovce unit within structural plan of the Western Carpathians - Engl. Summ. ZPN, Hodonín, 38, 3-8.
Vaňová, M. 1962: Grossforaminiferen aus dem Zentralkarpatischen Paläogen -Germ. Res. Geol. práce, Zošit, 63, 85-92.
Vaňová, M. 1964: Veľké foraminifery z hromošsko-šambronského antiklinálneho pásma. Zpr. o geol. výsk. r., 1962, 123-126. (In Slovak).
Žec B., Kaličiak M., Lexa J., Konečný V., Baňacký V., Rakús M., Potfaj M., Karoli S., Zlinská A., 1997: Vysvetlivky ku geologickej mape Vihorlatu m. 1:50 000. GSSR, Bratislava. (In Slovak)

Comments on the article „Neogene tectono-sedimentary megacycles in the Western Carpathians basins, their biostratigraphy and paleoclimatology“ by the authors N. Hudáčková, M. Kováč, V. Sitár, R. Pipík, K. Zagoršek & A. Zlinská

DIONÝZ VASS

Geological Survey of Slovak Republic, Mlynská dolina 1 817 04 Bratislava

In the Slovak Geological Magazine No 3-4/96 among the articles summarizing the results of investigations carried out under the Project of Geodynamic Development of the Western Carpathians is a paper by Hudáčková et al. As leader of the Problem No 5. „Geodynamic Development of the Carpathian arc in the Neogene“ of the above mentioned Project I had the possibility to study the manuscript of the article, before publishing. I called attention of the authors to some shortages and provided references of papers to help them made correct or at least confront their views with opinion of other autors. It has not happened so, therefore I use the possibility for critical remarks to the conncerned article.

The authors rather avoid to use the lithostratigraphical names, manifesting rigidity, proper to many Slovak geologists, to the Anglo-Saxon system of geological terminology, which however, was codified by Hedberg et al., on the one hand and in the Code of Czechoslovak Stratigraphical Terminology on the other hand (Chlupáč et al.,1968), which is till now obligatory for the Slovak geological community. Unfortunately, it is not so, what does not contribute to the good name of Slovak geology. Therefore in the article the formations are characterized and/or designated by long descriptive names, as for instance their „Ottnangian deposits of terrestrial or lake sediments without foraminifers“, corresponding to the Bukovinka Formation in present lithostratigraphical terminology. This formation is assigned by the authors to the Ottnangian, based on older studies by Čechovič (1952), Vass et al., (1979). More recent studies show that this formation is Eggenburgian in age as is shown by radiometric ages of rhyodacite tuffs intercalated in the formation, as well as by a subtropical to tropical flora. The Ottnangian is time period of global cooling (Vass et al., 1992; Vass 1995; and others). Conservativism in relation to lithostratigraphical terminology is documented by the authors using biostratigraphical terminology as Rzehakia (Oncophora) beds. The name is stiff and it is doubled, because there was a change of the index genus. Besides that, when acting as substitute for a lithostratigraphical unit, it should be translated in English not as Beds but as Member!

The mentioned Member (its formal name is Medokýš Member) is correlated with the Ottnangian. Any attention is paid to the evidences of the Member's younger age - Karpathian.. The Karpathian age is proved by foraminiferal assemblage. The Medokýš Mb represents the transgressive part of global sea level fluctuation cycle Tejas B 2.2, dated as 17,5-16,4 Ma B.P. The whole cycle corresponds to the chronostratigraphical stage of Karpathian.

Surprising is the self-quotation (Kováč et al.,1993) in connection with the statement that after the Lower Badenian the South Slovakian region has remained permanently dry land. This fact is already evident from the papers by Čechovič (for instance 1952; also from later papers Vass et al.,1979, 1983). In the more recent paper by Vass & Elečko et al., (1992) this is expressively mentioned in p.18.

During the Karpatian and Early Badenian there was no active basic volcanism in the West Carpathian region, as it results from the text (p. 357).

The characterization of the tectonic regime in the Karpatian-Early Badenian time in the hinterland area is not exhaustive. The authors mention the situation in the Pannonian region, but tectonic regime of the North Hungary as well as southern and central Slovakia is significantly different (see Vass 1995; Márton et al., 1995).

The authors do not clear up the mechanism, which during the Middle Badenian to Early Sarmatian, by the deeping of the subducted plate, should have influenced formation of the Western Carpathian basins and caused stretching of the Western Carpathian Internides in northeastern, later in eastern direction (p. 357).

The authors mention as new the intraarc basin nature of the Transcarpathian Basin (p. 357). This statement was already done in the paper by Vass et al., (1988) the co-author of which is one of the authors of the commented article.

In the characterisation of volcanism in the Sarmatian to Pontian time the authors left unmentioned significant manifestations of acid volcanism the products of which are gathered in the Jastrabá Formation in the Central Slovakian region. Otherwise, manifestations of acid volcanism are also known in eastern Slovakia in this time.

Some average curve of eustatic sea level changes in Western Carpathian Neogene basins (Fig.1) is misleading. On the curve for the time of formation of the terrestrial, and/or fluvial Bukovinka Formation, may be read a relatively deeper-water environment than for the Pannonian period when there was a caspibrackish rather deep lake spreaded in the main basins of the Western Carpathians and of the Pannonia. The authors did not consider as necessary to mention the scheme of relative sea level fluctuation, which was elaborated by Vass (1995) for the South Slovakian region. It is a pity, because so they would learn, for instance, that throughout the Early Miocene (with the exception of the Karpathian) the influence of global sea level changes in the South Slovakian, but obviously also in the whole Pannonian region was suppressed by regional tectonic factors (Vass 1995).

For the climate characterization of the individual periods the authors used first of all the floristic indicators, although interesting knowledge on the climate results from ecological evaluation of fish fauna, e.g. from the Fiľakovo Formation (Eggenburgian) on southern Slovakia as well as from the study of foraminiferal plankton, for instance, from Early Badenian marine sediments of the Western Carpathian basins. The character of weathering and weathering crusts is also a good climatic indicator to which the authors did not pay attention.

Why the authors used bipartite subdivision of the Badenian and Sarmatian? In compendia dealing with neostratotypes of these stages both are biostratigraphically subdivided into three substages and this subdivision is applied generally.

The article is especially depending on the angle of sight, which is given by the region, best known to the authors from autopsy. From this point of view one can have serious objections to the universality (in the frame of the Western Carpathians) of the discerned tectonosedimentary megacycles. They are mostly suitable for the Vienna Basin, but difficulties arise in their application to other basins (for instance, the Early - Middle Miocene megacycle in the East Slovakian Basin is divided by the Karpatian crisis of salinity); in southern Slovakia only the lower part of the Eggenburgian corresponds to the Early Miocene megacycle. The higher cycle starts in the Ottnangian but ends after the Karpatian by huge erosional truncation. In the Early Badenian a new cycle begins, which disappears soon as a consequence of volcanic paroxysm in the Central Slovakian region and of uplift following after last counterclockwise rotation in this region. By the way, rotations about which one of the authors wrote pioneer papers for the Miocene time in the Western Carpathians, are not taken into consideration at all.

It results from the above mentioned that the authors had ambitious aims to characterize tectono-sedimentary cycles in Western Carpathians Neogene basins in a complex way, but have not mastered the complicated and comprehensive problems.

Review of the paper of authors J. Soták, J. Bebej & A. Biroň: Detrital analysis of the Paleogene flysch deposits of the Levoča Mts.: evidence for sources and paleogeography.

PAVOL GROSS[1] & IVAN FILO[1]

[1]Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava

After publication of the above introduced paper (Soták, Bebej & Biroň, 1996) the competent workers of Geological Survey of Slovak Republic feel at least to be embarassed from both technical and ethic point of view.

The works connected with the research of the Levoča Mts. region (- Poprad Depression, Hornád Depression, Levoča Mts. and Šariš Paleogene/, financed by a common source and coordinated by common control bodies, were conducted in the way that all geologists and geophysicists of cooperating institutions were fully informed about the progress on the work and, above all, they were informed about new consequences resulting from the work. The common discussions and excursions provided a concrete acquaintance with problems directly in the field at selected localities.

Inspite of maximum effort of the authority which ordered the work in order to apply a team work, which seemingly was really good and almost without problems, it seems today that the authors of the above mentioned paper do not want to accept or to see somehow the work of the team from the Geological Survey of Slovak Republic. The work, which was achieved by this team consisting of mappers, palaeontologists and petrographers working at the Geological Survey in Bratislava and Košice, is proved by results.

The paper, except not enough proved ideas, gives incorrect information, in many aspects it is deceitful, informs wrongly and unambiguously violates basic ethical principles.

1. On the one hand the authors ignore the introduced and in the Inner-Carpathian Paleogene commonly used terms (Borové, Huta Formation....) substituing them by genetic-lithologic descriptions (transgressive lithofacies, clayey lithofacies), on the other hand they use new terms (Kežmarok Beds, Kluknava Beds), which are often used only in manuscripts. Not even in one case they quote a source from which they take information.

Kežmarok Beds were first described and named in manuscripts of Gross et al. 1994, 1995, 1996, Filo et al. 1994, 1995, the definition of the term has been ready for publishing today (Gross in press). It would be ethical to refer above mentioned works, which are archived at Geological Survey of Slovak Republic and at Nafta Oil Company a.s., Gbely.

Tomášovce Beds were described and named in manuscripts of Filo et al. 1994, 1995, Karoli et al. 1994, Gross et al. 1996, the definition of the term has been submitted according to the rules of the stratigraphic classification in the paper of Filo and Siránova 1996.

Kluknava Beds - the term in this form has not yet been published. It is not clear whether it was not used by authors in their manuscripts, which are not publicaly available. Even in this case the quotation is missing. Andrusov (1965) used for basal Paleogene in the northern part of the Spiš - Gemer Rudohorie Mts. only a term kluknava development of Súľov Formation. Filo et al. (1994) used a modified form (kluknava development) to mark continental conglomerates and sandstones in the surroundings of Hrabušice.

Use of new lithostratigraphic formations without any closer description is extremely improper and evokes a terminologic chaos and undesirable synonymity (defiinition of the lithostratigraphic unit, probably identical to Kluknava Beds, is submitted to press (Filo and Siranova in press).

2. Authors state that ... the studied area was probably overlain by transgression in the Early Oligocene (when numulite base is missing). The marine transgression entered here by flat promontories of alluvial fan deposits (kluknava deposits). The transgressive lithofacies is represented by tomášovce beds...

- The Oligocene age of Borové Formation (transgressive lithofacies) is not proved by anything, on the contrary, all the data available (macrofauna of the lower part of Borové Formation, macrofauna and macroflora of Tomášovce Beds, microfauna, microflora and nanoflora of the overlying Huta Formation - Volfová 1961, 1962, 1963, Gross, Papšová and Kohler 1973, Plička 1987, Korábová 1990, Raková and Snopková in Nagy et al. 1994, Raková, Samuel, Snopková and Zecová in Gross et al. 1996 etc.) suggest that the transgression had to start (at the latest) during the Priabonian. The absence of numulites v is not caused by Oligocene age of the Borové Formation, but it is caused by other factors (decrease of salinity and high sediment content in the nearshore areas determined by entering rivers and in the substantial part of the area unsuitable non-carbonatic substratum).

-Tomášovce Beds only represent the uppermost part of the Borové Formation, e.g. the termination of transgressive cycle. This lithostratigraphic unit is specific for Hornad Depression and Saris upland, it absents in other regions (Liptov Depression, Poprad Depression, Orava region etc.). The really basal transgressive lithofacies in the area is represented by several tens of meters thick carbonate and polymictic conglomerates, breccias, sandstones and sandstone limestones with marine fauna underlying Tomášovce Beds. They are excelently exposed for example in the break gate of the Hornád river in the surroundings of Čingov (Marschalko and Gross in Mahel et al. 1963, Filo et al. 1994, Gross et al. 1994, Volfová 1961, 1962, 1963). A question of the presence of the transgressive lithofacies in areas, where the Tomašovce Beds are underlain by deposits of continental (fluvial) resp. deltaic origin (Marschalko 1970, Filo et al. 1995) is up to discussion.

3. ... The flysch of the Late Oligocene has a distal character in the region, proved by non-cyclic structures of lobes....

- It is not clear for us, how is the distality of the Late Oligocene flysch (how was proved the Late Oligocene??) related to the Kezmarok Beds, which characteristics is too far from distal deposits. It is a thick rhytmic flysch where medium and coarse-grained sandstones and gravelit fraction on the base of beds (Ta division sensu Bouma 1962) strongly prevail.

4. There is a blockdiagram on Fig. 2 showing evolution of so called East-Slovakian collision zone in the Late Oligocene .

-It does not appear to us logic that in the Oligocene the Inner-Carpathian Paleogene Basin immediately neighbours the Magura trough along a fictive plate line. How can touch one marine basin the another? It had to be a sufficiently wide, geologically variable mainland at that time, which separated two marine provinces with entirely different bed units and different sedimentary regime.

5. ... besides axial currents (E-W direction), coarse-detritic deposits also entered the basin laterally... the source of the deposits occurred on slopes of the active Central-Carpathian plate...

- What is considered by authors as an active margin if we can not find it in the blockdiagram? Might they be some non-emergent submarine slopes?

6. The authors of the paper write further: ... the occurrence of serpentinite sandstones were found in the most distal flysch facies occurring at the contact of Šambrone zone with Klippen Belt... The origin of the serpentinite detrit is necessary to seek in the oceanic crust (oceanic plate) pull up at the collision edge with the plate of Central-Carpathian plate, in the zone of the subducting trench...

-A question again emerges how is it possible to tolk about trench (or about a margin of a continental block) if it is not depicted on Fig. 2. As it is known from numerous boreholes, the deposits of Paleogene Subtatric Group in the area are directly underlain by rock complex of Choč nappe in the south, Križnan nappe in the northern part (as far as to the boundary with Klippen Belt). Do perhaps authors think that the Magura trough is underlain by oceanic crust and that the crust would possibly form an emergent mainland (trench) in areas of the Late Eocene "Klippen Belt"?

The presence of pebbles consisting of ultramafic rocks (of the type of enstatic dunit from Sedlice) with serpentinite (Šalát 1954) is known in the Paleogene conglomerates occurring in the surroundings of Margecany. Is it not simplier to seek for the source of serpentinite occurring in the described sandstones in the above mentioned areas (what would be consistent with dominant palaeocurrent directions - Marschalko 1978)? Our mapping and petrographic studies proved that basically there are two local occurrences of serpentinite sandstone. This type of the sandstone has not been found at other localities of the region. Is it necessary immediately look for oceanic crust, territorially not closer localized, on the basis of local small occurrences?

7. Authors assume in the "structure of Šambron zone" (Šambron Beds? or tectonic Unit?) occurrence of conglomerates or coarse-grained clastics with clasts which should partly originated in the contemporary exposed rock units of Inačevo-Kričevo Zone. They prove it by (except findings of the clasts from the Inner Carpathians) occurrence of granitoid clasts and crystalline rocks (gneisses, mica shists, amphibolites, quartzite etc.) and by a certain part of dark phyllites, calcareous phyllites and marmors. They also describe a long time known fact of the carbonite detritus decreasing (in sandstones and conglomerates of the upper formations as Borovo Formation) in the Levoča Mts.. It should also prove that in the Late Oligocene (there were not given evidence about this age!!) Inačevo-Kričevo Unit was also exhumed in the east.

- Authors did not notice a fact, that it is possible to find the lithologic types of pebbles, which they named, nearly everywhere in Slovakia where the upper formations of the Paleogene Subtatric Group occur. Whether it goes about the region of Paprad Depression, Liptov area, Orava area or Horná Nitra area etc. generally a decrease of the carbonate detritus is observed from the base (Borové Formation) upward and coevally increasing content of very variable rock types of granitoid characters, crystalline schists, quartz etc. (Gross et al. 1980, 1993). The rock types described by them are not possible to consider as an exact evidence of exposed Inačevo - Kričevo zone supplying sediments because manifestation of this zone could be evidenced even in Horna Nitra region (what is perhaps already nonsense). As to the age, this variable clastisc should vary from Priabonian to the Early Oligocene.

Considering the above given lithologic content of conglomerates (calcareous and dark phyllites, marmors etc.) as an evidence for today completely colmated zone which is only known from sporadic boreholes, seems to us not much reliable, more wished as proved. We do not have any reasons to negate existency of Inačevo-Kričevo Zone as a possible source area of a part of clastic material, but the facts given are not convincing.

Instructions to authors

General instruction

The editorial Board of the Dionýz Štúr Institute of Geology accepts manuscripts in English language.

The Editorial Board accepts or refuses a manuscript with regard to the reviewer's opinion. The author is informed of the refusal within 14 days from the decision of the Editorial Board. Accepted manuscript is prepared for publication in an appropriate issue of the magazine. The author(s) and the publishers enter a contract establishing the rights and duties of both parties during editorial preparation and printing, until the time of publishing of the paper.

Text layout

The text should be arranged as follows: full name of the author(s); title of the paper, number of supplements (in brackets below the title, e.g. 5 figs., 4 tabs.); key words - maximum 5 words arranged successively from general to special terms; abstract (max. 15 lines presenting principal results); in a footnote on the first page, name of the author(s), as well as his (their) professional or private address.

The text of the paper should be logically divided. For the purpose of typology, the author may use a hierarchic division of chapters and sub-chapters, using numbers with their titles. The editorial board reserves the right to adjust the type according to generally accepted rules even if the author has not done this.

Names of cited authors in the text are written without first names or initials (e.g. Štúr, 1868), the names of co-authors are divided (e.g. Mišík & Sýkora, 1981). The name(s) is followed by a comma. If there are more authors, the first one, or the first two only are cited, adding et al. and publication year.

Mathematical and physical symbols of units, such as %, ‰, °C should be preceded by a space, e.g. 60 %, 105 °C etc. Abbreviations of the units such as second, litre atc. should be written without a period. Compass bearings may be substituted by the abbreviations E, W, NW, SSE etc. Brackets (parentheses) are to be indicated as should be printed, i.e. square brackets, parentheses or compound. Dashes should be typed as double hyphens.

If a manuscript is typed, 2 copies are required, including figures. Required is A4 page size, 30 text lines with 60 characters, including spaces, typed with line spacing No. 2. The author should mark these parts of a text which should be printed in different type with a vertical line on the left side of the manuscript. Paragraphs are marked with 1 tab space from the left margin, or by a typographic symbol. Greek characters should be written by hand and followed by their description in parentheses, e.g. (sigma, omega, etc.). Indices and exponents should be properly marked.

If the text is delivered on a diskette (3.5" or 5.25"), it is necessary to send also one hard copy. The publishers shall accept the following text formats:
*.doc (Word for Windows 6.0, 7.0, 8.0).

Tables and figures

Tables shall be accepted in a size of up to A4, numbered in the same way as in text.

Tables should be typed on separate sheets of the same size as text, with normal type. The author is asked to mark in the text where the table should be inserted. Short explanations attached to a table, should be included on the same sheet. If the text is longer, it should be typed on a separate sheet.

In contributions delivered on a diskette, tables may be written using a text editor (Word for Windows, Word Perfect, T602), or a spreadsheet (Quattro Pro, Excel) and delivered as a separate file. Characters in the table should not be less than 8 point large.

Figures should be presented in black-and-white, in exceptional cases also in colour. Figures are to be presented by the author simultaneously with the text of the paper, in two copies, or on a diskette + one hard copy. Graphs, sketches, profiles and maps must be always drawn separately. High-quality copies are accepted as well. Captions should be typed outside the figure. The graphic supplements should be numbered on the reverse side, along with the orientation of the figures. Large-size supplements are accepted only exceptionally. Photographs intended for publishing should be sharp, contrasting, on shiny paper. High quality colour photographs will only be accepted depending on the judgement of the technical editors.

If a picture is delivered in a digital form, the following formats will be accepted: *.cdr, *.bmp, *.tiff, *.wpg, *.fga, *.giff, *.jpg, *.pcx. Other formats are to be consulted with the editors.

References

- list of references should only include papers cited in text
- the items are to be listed alphabetically, with hanging indent in the second and following lines
  authors are to be cited with initials following the family name.

Example

Cícha I. & Seneš J., 1971: Probleme der Beziehung zwischen Bio- und Chronostratigraphie des jungeren Tertiärs. Geol. Zbor. (Bratislava), 56, 2, 529 - 640.

Matula M., 1969: Regional engineering geology of Czechoslovak Carpathians. 1. Ed. Maheľ, M., Bratislava, Vyd. Slov. Akad. Vied, 225 p.

Andrusov D., Bystrický J. & Fusán O., 1973: Outline of the Structure of the West Carpathians. Guide-book for geol. exc. X. Congr. CBGA, Geol. Úst. D. Štúra, Bratislava, 5 - 44.

- proceedings should be cited as follows:
  1. family name and initials of author(s)
  2. publication year
  3. title of paper
  4. title of proceedings
  5. editor(s)
  6. place of publishing
  7. publishing house
  8. page range
  9. non published reports should be denoted "manuscript" and the place of archive should be given.

Proofs

The translator as well as the author(s) are obliged to correct the errors which are due to typing and technical arrangements. The first proofs are sent to author(s) as well as to the translator. The second proof is provided only to the editorial office. It will be sent to authors upon request.

The proofs must be marked clearly and intelligibly, to avoid further errors and doubts. Common typographic symbols are to be used, the list and meaning of which will be provided by the editorial office. Each used symbol must also appear on the margin of the text, if possible on the same line where the error occurred. The deadlines and conditions for proof-reading shall be stated in the contract.

Final remarks

These instructions are obligatory to all authors. Exceptions may be permitted by the Editorial Board or the managing editor. Manuscripts not complying with these instructions shall be returned to the authors.

1. Editorial Board reserves the right to publish preferentially invited manuscript and to assemble thematic volumes,
2. Editorial Board sits four times a year and closing dates for individual volumes will be on every 15th day of March, June, September and December.
3. To refer to one Magazine please use the following abbreviations: Slovak Geol. Mag. No. .... D. Štúr Publ. Bratislava.